

WHAT IS CLAIMED IS:

1. A object attribute acquisition and analysis system completely contained within a single housing of compact lightweight construction .

2. An object attribute acquisition and analysis system, which is capable of (1) acquiring and analyzing in real-time the physical attributes of objects such as, for example, (i) the surface reflectively characteristics of objects, (ii) geometrical characteristics of objects, including shape measurement, (iii) the motion (i.e. trajectory) and velocity of objects, as well as (iv) bar code symbol, textual, and other information-bearing structures disposed thereon, and (2) generating information structures representative thereof for use in diverse applications including, for example, object identification, tracking, and/or transportation/routing operations.

3. An object attribute acquisition and analysis system, wherein a multi-wavelength (i.e. color-sensitive) Laser Doppler Imaging and Profiling (LDIP) subsystem is provided for acquiring and analyzing (in real-time) the physical attributes of objects such as, for example, (i) the surface reflectively characteristics of objects, (ii) geometrical characteristics of objects, including shape measurement, and (iii) the motion (i.e. trajectory) and velocity of objects.

4. An object attribute acquisition and analysis system, wherein an image formation and detection (i.e. camera) subsystem is provided having (i) a planar laser illumination and monochromatic imaging (PLIIM) subsystem, (ii) intelligent auto-focus/auto-zoom imaging optics, and (iii) a high-speed electronic image detection array with height/velocity-driven photo-integration time control to ensure the capture of images having constant image resolution (i.e. constant dpi) independent of package height.

5. An object attribute acquisition and analysis system, wherein an advanced image-based bar code symbol decoder is provided for reading 1-D and 2-D bar code symbol labels on objects, and an advanced optical character recognition (OCR) processor is provided for reading textual information, such as alphanumeric character strings, representative within digital images that have been captured and lifted from the system.

6. An object attribute acquisition and analysis system for use in the high-speed parcel, postal and material handling industries.

7. An object attribute acquisition and analysis system, which is capable of being used to identify, track and route packages, as well as identify individuals for security and personnel control applications.

8. An object attribute acquisition and analysis system which enables bar code symbol reading of linear and two-dimensional bar codes, OCR-compatible image lifting, dimensioning, singulation, object (e.g. package) position and velocity measurement, and label-to-parcel tracking from a single overhead-mounted housing measuring one 20" x 20" x 8".

9. An object attribute acquisition and analysis system which employs a built-in source for producing a planar laser illumination beam that is coplanar with the field of view of the imaging optics used to form images on an electronic image detection array, thereby eliminating the need for large, complex, high-power power consuming sodium vapor lighting equipment used in conjunction with most industrial CCD cameras.

10. An object attribute acquisition and analysis system, wherein the all-in-one (i.e. unitary) construction simplifies installation, connectivity, and reliability for customers as it utilizes a single input cable for supplying input (AC) power and a single output cable for outputting digital data to host systems.

11. An object attribute acquisition and analysis system, wherein such systems can be configured to construct multi-sided tunnel-type imaging systems, used in airline baggage handling systems, as well as in postal and parcel identification, dimensioning and sortation systems.

12. An object attribute acquisition and analysis system, for use in (i) automatic checkout solutions installed within retail shopping environments (e.g. supermarkets), (ii) security and people analysis applications, (iii) object and/or material identification and inspection systems, as well as (iv) diverse portable, in-counter and fixed applications in virtual any industry.

13. An object attribute acquisition and analysis system in the form of a high-speed package dimensioning and identification system, wherein the PLIIM subsystem projects a field of view through a first light transmission aperture formed in the system housing, and a pair of planar laser illumination beams through second and third light transmission apertures which are optically isolated from the first light transmission aperture to prevent laser beam scattering

within the housing of the system, and the LDIP subsystem projects a pair of laser beams at different angles through a fourth light transmission aperture.

14. An automated unitary-type package identification and measuring system (i.e. contained within a single housing or enclosure), wherein a PLIIM-based scanning subsystem is used to read bar codes on packages passing below or near the system, while a package dimensioning subsystem is used to capture information about the package prior to being identified.

15. An automated package identification and measuring system, wherein Laser Detecting And Ranging (LADAR-based) scanning methods are used to capture two-dimensional range data maps of the space above a conveyor belt structure, and two-dimensional image contour tracing methods are used to extract package dimension data therefrom.

16. A PLIM which embodies an optical technique that effectively destroys the spatial and/or temporal coherence of the laser illumination sources that are used to generate planar laser illumination beams (PLIBs) within PLIIM-based systems.

17. A PLIM, wherein the spatial coherence of the illumination sources is destroyed by creating multiple "virtual" illumination sources that illuminate the object at different angles, over the photo-integration time period of the electronic image detection array used in the IFD module.

18. A PLIM which embodies an optical technique that effectively reduces speckle-noise pattern at an image detection array by destroying the spatial and/or temporal coherence of the laser illumination sources are used to generate planar laser illumination beams (PLIBs) within the PLIIM-based system.

19. A PLIM, wherein the spatial coherence of the illumination sources is destroyed by creating multiple "virtual" illumination sources that illuminate the object at different points in space, over the photo-integration time period of the electronic image detection array used in the system.

20. A unitary object attribute acquisition and analysis system which is capable of (1) acquiring and analyzing in real-time the physical attributes of objects such as, for example, (i)

the surface reflectivity characteristics of objects, (ii) geometrical characteristics of objects, including shape measurement, (iii) the motion (i.e. trajectory) and velocity of objects, as well as (iv) bar code symbol, textual, and other information-bearing structures disposed thereon, and (2) generating information structures representative thereof for use in diverse applications including, for example, object identification, tracking, and/or transportation/routing operations.

21. A unitary object attribute acquisition and analysis system, wherein a multi-wavelength (i.e. color-sensitive) Laser Doppler Imaging and Profiling (LDIP) subsystem is provided for acquiring and analyzing (in real-time) the physical attributes of objects such as, for example, (i) the surface reflectivity characteristics of objects, (ii) geometrical characteristics of objects, including shape measurement, and (iii) the motion (i.e. trajectory) and velocity of objects.

22. A unitary object attribute acquisition and analysis system, wherein an image formation and detection (i.e. camera) subsystem is provided having (i) a planar laser illumination and imaging (PLIIM) subsystem, (ii) intelligent auto-focus/auto-zoom imaging optics, and (iii) a high-speed electronic image detection array with height/velocity-driven photo-integration time control to ensure the capture of images having constant image resolution (i.e. constant dpi) independent of package height.

23. A unitary object attribute acquisition and analysis system, wherein an advanced image-based bar code symbol decoder is provided for reading 1-D and 2-D bar code symbol labels on objects, and an advanced optical character recognition (OCR) processor is provided for reading textual information, such as alphanumeric character strings, representative within digital images that have been captured and lifted from the system.

24. A unitary object attribute acquisition and analysis system which enables bar code symbol reading of linear and two-dimensional bar codes, OCR-compatible image lifting, dimensioning, singulation, object (e.g. package) position and velocity measurement, and label-to-parcel tracking from a single overhead-mounted housing measuring less than or equal to 20 inches in width, 20 inches in length, and 8 inches in height.

25. A unitary object attribute acquisition and analysis system which employs a built-in source for producing a planar laser illumination beam that is coplanar with the field of view (FOV) of the imaging optics used to form images on an electronic image detection array,



thereby eliminating the need for large, complex, high-power power consuming sodium vapor lighting equipment used in conjunction with most industrial CCD cameras.

26. A unitary object attribute acquisition and analysis system which can be configured to construct multi-sided tunnel-type imaging systems, used in airline baggage-handling systems, as well as in postal and parcel identification, dimensioning and sortation systems.

27. A unitary object attribute acquisition and analysis system, for use in (i) automatic checkout solutions installed within retail shopping environments (e.g. supermarkets), (ii) security and people analysis applications, (iii) object and/or material identification and inspection systems, as well as (iv) diverse portable, in-counter and fixed applications in virtual any industry.

28. A unitary object attribute acquisition and analysis system in the form of a high-speed package dimensioning and identification system, wherein the PLIIM subsystem projects a field of view through a first light transmission aperture formed in the system housing, and a pair of planar laser illumination beams through second and third light transmission apertures which are optically isolated from the first light transmission aperture to prevent laser beam scattering within the housing of the system, and the LDIP subsystem projects a pair of laser beams at different angles through a fourth light transmission aperture.

29. A unitary-type package identification and measuring system contained within a single housing or enclosure, wherein a PLIIM-based scanning subsystem is used to read bar codes on packages passing below or near the system, while a package dimensioning subsystem is used to capture information about attributes (i.e. features) about the package prior to being identified.

30. A planar laser illumination and imaging (PLIIM) system which employs high-resolution wavefront control methods and devices to reduce the power of speckle-noise patterns within digital images acquired by the system.

31. A PLIIM-based system, in which planar laser illumination beams (PLIBs) rich in spectral-harmonic components on the time-frequency domain are optically generated using principles based on wavefront spatio-temporal dynamics.

32. A PLIIM-based system, in which planar laser illumination beams (PLIBs) rich in spectral-harmonic components on the time-frequency domain are optically generated using principles based on wavefront non-linear dynamics.

33. A PLIIM-based system, in which planar laser illumination beams (PLIBs) rich in spectral-harmonic components on the spatial-frequency domain are optically generated using principles based on wavefront spatio-temporal dynamics.

34. A PLIIM-based system, in which planar laser illumination beams (PLIBs) rich in spectral-harmonic components on the spatial-frequency domain are optically generated using principles based on wavefront non-linear dynamics.

35. A PLIIM-based system, in which planar laser illumination beams (PLIBs) rich in spectral-harmonic components are optically generated using diverse electro-optical devices selected from the group consisting of micro-electro-mechanical devices (MEMs) (e.g. deformable micro-mirrors), optically-addressed liquid crystal (LC) light valves, liquid crystal (LC) phase modulators, micro-oscillating reflectors (e.g. mirrors or spectrally-tuned polarizing reflective CLC film material), micro-oscillating refractive-type phase modulators, micro-oscillating diffractive-type micro-oscillators, as well as rotating phase modulation discs, bands, rings and the like.

36. A planar laser illumination and imaging (PLIIM) system and method which employs a planar laser illumination array (PLIA) and electronic image detection array which cooperate to effectively reduce the speckle-noise pattern observed at the image detection array of the PLIIM system by reducing or destroying either (i) the spatial and/or temporal coherence of the planar laser illumination beams (PLIBs) produced by the PLIAs within the PLIIM system, or (ii) the spatial and/or temporal coherence of the planar laser illumination beams (PLIBs) that are reflected/scattered off the target and received by the image formation and detection (IFD) subsystem within the PLIIM system.

37. A planar laser illumination and imaging (PLIIM) system comprising: a planar laser illumination array (PLIA) and electronic image detection array which cooperate to effectively reduce the speckle-noise pattern observed at the image detection array of the PLIIM system by reducing or destroying either (i) the spatial and/or temporal coherence of the planar laser illumination beams (PLIBs) produced by the PLIAs within the PLIIM system, or (ii) the spatial and/or temporal coherence of the planar laser illumination beams (PLIBs) that are

reflected/scattered off the target and received by the image formation and detection (IFD) subsystem within the PLIIM system.

38. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the method is based on temporal intensity modulating the composite-type return PLIB produced by the composite PLIB illuminating and reflecting and scattering off an object so that the return composite PLIB detected by the image detection array in the IFD subsystem constitutes a temporally coherent-reduced laser beam and, as a result, numerous time-varying (random) speckle-noise patterns are detected over the photo-integration time period of the image detection array, thereby allowing these time-varying speckle-noise patterns to be temporally and spatially averaged and the RMS power of observed speckle-noise patterns reduced.

39. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein (i) the returned laser beam produced by the transmitted PLIB illuminating and reflecting/scattering off an object is temporal-intensity modulated according to a temporal intensity modulation (e.g. windowing) function (TIMF) so as to modulate the phase along the wavefront of the composite PLIB and produce numerous substantially different time-varying speckle-noise patterns at image detection array of the IFD Subsystem, and (ii) temporally and spatially averaging the numerous time-varying speckle-noise patterns at the image detection array during the photo-integration time period thereof, thereby reducing the RMS power of the speckle-noise patterns observed at the image detection array.

40. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein temporal intensity modulation techniques which can be used to carry out the method include, for example: high-speed electro-optical (e.g. ferro-electric, LCD, etc.) shutters located before the image detector along the optical axis of the camera subsystem; and any other temporal intensity modulation element arranged before the image detector along the optical axis of the camera subsystem, and through which the received PLIB beam may pass during illumination and image detection operations.

41. A method of and apparatus for speckle-noise pattern reduction based on the principle of spatially phase modulating the transmitted planar laser illumination beam (PLIB) prior to illuminating a target object (e.g. package) therewith so that the object is illuminated

with a spatially coherent-reduced planar laser beam and, as a result, numerous substantially different time-varying speckle-noise patterns are produced and detected over the photo-integration time period of the image detection array (in the IFD subsystem), thereby allowing these speckle-noise patterns to be temporally averaged and possibly spatially averaged over the photo-integration time period and the RMS power of observable speckle-noise pattern reduced.

42. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the method involves modulating the spatial phase of the composite-type "transmitted" planar laser illumination beam (PLIB) prior to illuminating an object (e.g. package) therewith so that the object is illuminated with a spatially coherent-reduced laser beam and, as a result, numerous time-varying (random) speckle-noise patterns are produced and detected over the photo-integration time period of the image detection array in the IFD subsystem, thereby allowing these speckle-noise patterns to be temporally averaged and/or spatially averaged and the observable speckle-noise pattern reduced.

43. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein (i) the spatial phase of the transmitted PLIB is modulated along the planar extent thereof according to a spatial phase modulation function (SPMF) so as to modulate the phase along the wavefront of the PLIB and produce numerous substantially different time-varying speckle-noise patterns to occur at the image detection array of the IFD Subsystem during the photo-integration time period of the image detection array thereof, and also (ii) the numerous time-varying speckle-noise patterns produced at the image detection array are temporally and/or spatially averaged during the photo-integration time period thereof, thereby reducing the speckle-noise patterns observed at the image detection array.

44. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the spatial phase modulation techniques that can be used to carry out the method include, for example: mechanisms for moving the relative position/motion of a cylindrical lens array and laser diode array, including reciprocating a pair of rectilinear cylindrical lens arrays relative to each other, as well as rotating a cylindrical lens array ring structure about each PLIM employed in the PLIIM-based system; rotating phase modulation discs having multiple sectors with different refractive indices to effect different degrees of phase delay along the wavefront of the PLIB transmitted (along different optical paths) towards the object to be illuminated; acousto-optical

Bragg-type cells for enabling beam steering using ultrasonic waves; ultrasonically-driven deformable mirror structures; a LCD-type spatial phase modulation panel; and other spatial phase modulation devices.

5           45.    A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the transmitted planar laser illumination beam (PLIB) is spatially phase modulated along the planar extent thereof according to a (random or periodic) spatial phase modulation function (SPMF) prior to illumination of the target object with the PLIB, so as to modulate the phase along the wavefront of the PLIB and produce numerous substantially different time-varying speckle-noise pattern at the image detection array, and temporally and spatially average these speckle-noise patterns at the image detection array during the photo-integration time period thereof to reduce the RMS power of observable speckle-pattern noise.

10           46.    A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the spatial phase modulation techniques that can be used to carry out the method of despeckling include, for example: mechanisms for moving the relative position/motion of a cylindrical lens array and laser diode array, including reciprocating a pair of rectilinear cylindrical lens arrays relative to each other, as well as rotating a cylindrical lens array ring structure about each PLIM employed in the PLIIM-based system; rotating phase modulation discs having multiple sectors with different refractive indices to effect different degrees of phase delay along the wavefront of the PLIB transmitted (along different optical paths) towards the object to be illuminated; acousto-optical Bragg-type cells for enabling beam steering using ultrasonic waves; ultrasonically-driven deformable mirror structures; a LCD-type spatial phase modulation panel; and other spatial phase modulation devices.

15           47.    A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein a pair of refractive cylindrical lens arrays are micro-oscillated relative to each other in order to spatial phase modulate the planar laser illumination beam prior to target object illumination.

20           48.    A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein a pair of light diffractive (e.g. holographic) cylindrical lens arrays are micro-oscillated relative to each

other in order to spatial phase modulate the planar laser illumination beam prior to target object illumination.

5 49. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein a pair of reflective elements are micro-oscillated relative to a stationary refractive cylindrical lens array in order to spatial phase modulate a planar laser illumination beam prior to target object illumination.

10 50. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the planar laser illumination (PLIB) is micro-oscillated using an acoustic-optic modulator in order to spatial phase modulate the PLIB prior to target object illumination.

15 51. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the planar laser illumination (PLIB) is micro-oscillated using a piezo-electric driven deformable mirror structure in order to spatial phase modulate said PLIB prior to target object illumination.

20 52. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the planar laser illumination (PLIB) is micro-oscillated using a refractive-type phase-modulation disc in order to spatial phase modulate said PLIB prior to target object illumination.

25 53. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the planar laser illumination (PLIB) is micro-oscillated using a phase-only type LCD-based phase modulation panel in order to spatial phase modulate said PLIB prior to target object illumination.

30 54. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the planar laser illumination (PLIB) is micro-oscillated using a refractive-type cylindrical lens array ring structure in order to spatial phase modulate said PLIB prior to target object illumination.

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55. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the planar laser illumination (PLIB) is micro-oscillated using a diffractive-type cylindrical lens array ring structure in order to spatial intensity modulate said PLIB prior to target object illumination.

56. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the planar laser illumination (PLIB) is micro-oscillated using a reflective-type phase modulation disc structure in order to spatial phase modulate said PLIB prior to target object illumination.

57. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein a planar laser illumination (PLIB) is micro-oscillated using a rotating polygon lens structure which spatial phase modulates said PLIB prior to target object illumination.

58. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, based on reducing the temporal coherence of the planar laser illumination beam before it illuminates the target object by applying temporal intensity modulation techniques during the transmission of the PLIB towards the target.

59. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, based on the principle of temporal intensity modulating the transmitted planar laser illumination beam (PLIB) prior to illuminating a target object (e.g. package) therewith so that the object is illuminated with a spatially coherent-reduced planar laser beam and, as a result, numerous substantially different time-varying speckle-noise patterns are produced and detected over the photo-integration time period of the image detection array (in the IFD subsystem), thereby allowing these speckle-noise patterns to be temporally averaged and possibly spatially averaged over the photo-integration time period and the RMS power of observable speckle-noise pattern reduced.

60. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the method involves modulating the temporal intensity of the composite-type "transmitted" planar laser illumination beam (PLIB) prior to illuminating an object (e.g. package) therewith so that



the object is illuminated with a temporally coherent-reduced laser beam and, as a result, numerous time-varying (random) speckle-noise patterns are produced and detected over the photo-integration time period of the image detection array in the IFD subsystem, thereby allowing these speckle-noise patterns to be temporally averaged and/or spatially averaged and the observable speckle-noise pattern reduced.

61. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the transmitted planar laser illumination beam (PLIB) is temporal intensity modulated prior to illuminating a target object (e.g. package) therewith so that the object is illuminated with a temporally coherent-reduced planar laser beam and, as a result, numerous substantially different time-varying speckle-noise patterns are produced and detected over the photo-integration time period of the image detection array (in the IFD subsystem), thereby allowing these speckle-noise patterns to be temporally averaged and/or spatially averaged and the observable speckle-noise patterns reduced.

62. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, based on temporal intensity modulating the transmitted PLIB prior to illuminating an object therewith so that the object is illuminated with a temporally coherent-reduced laser beam and, as a result, numerous time-varying (random) speckle-noise patterns are produced at the image detection array in the IFD subsystem over the photo-integration time period thereof, and the numerous time-varying speckle-noise patterns are temporally and/or spatially averaged during the photo-integration time period, thereby reducing the RMS power of speckle-noise pattern observed at the image detection array.

63. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein (i) the transmitted PLIB is temporal-intensity modulated according to a temporal intensity modulation (e.g. windowing) function (TIMF) causing the phase along the wavefront of the transmitted PLIB to be modulated and numerous substantially different time-varying speckle-noise patterns produced at image detection array of the IFD Subsystem, and (ii) the numerous time-varying speckle-noise patterns produced at the image detection array are temporally and/or spatially averaged during the photo-integration time period thereof, thereby reducing the RMS power of RMS speckle-noise patterns observed (i.e. detected) at the image detection array.



64. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein temporal intensity modulation techniques which can be used to carry out the method include, for example: visible mode-locked laser diodes (MLLDs) employed in the planar laser illumination array; electro-optical temporal intensity modulation panels (i.e. shutters) disposed along the optical path of the transmitted PLIB; and other temporal intensity modulation devices.

65. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein temporal intensity modulation techniques which can be used to carry out the first generalized method include, for example: mode-locked laser diodes (MLLDs) employed in a planar laser illumination array; electrically-passive optically-reflective cavities affixed external to the VLD of a planar laser illumination module (PLIM; electro-optical temporal intensity modulators disposed along the optical path of a composite planar laser illumination beam; laser beam frequency-hopping devices; internal and external type laser beam frequency modulation (FM) devices; and internal and external laser beam amplitude modulation (AM) devices.

66. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the planar laser illumination beam is temporal intensity modulated prior to target object illumination employing high-speed beam gating/shutter principles.

67. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the planar laser illumination beam is temporal intensity modulated prior to target object illumination employing visible mode-locked laser diodes (MLLDs).

68. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the planar laser illumination beam is temporal intensity modulated prior to target object illumination employing current-modulated visible laser diodes (VLDs) operated in accordance with temporal intensity modulation functions (TIMFS) which exhibit a spectral harmonic constitution that results in a substantial reduction in the RMS power of speckle-pattern noise observed at the image detection array of PLIIM-based systems.

5 69. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, based on reducing the temporal-coherence of the planar laser illumination beam before it illuminates the target object by applying temporal phase modulation techniques during the transmission of the PLIB towards the target.

10 70. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, based on the principle of temporal phase modulating the transmitted planar laser illumination beam (PLIB) prior to illuminating a target object (e.g. package) therewith so that the object is illuminated with a temporal coherent-reduced planar laser beam and, as a result, numerous substantially different time-varying speckle-noise patterns are produced and detected over the photo-integration time period of the image detection array (in the IFD subsystem), thereby allowing these speckle-noise patterns to be temporally averaged and possibly spatially averaged over the photo-integration time period and the RMS power of observable speckle-noise pattern reduced.

15 71. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the method involves modulating the temporal phase of the composite-type "transmitted" planar laser illumination beam (PLIB) prior to illuminating an object (e.g. package) therewith so that the object is illuminated with a temporal coherent-reduced laser beam and, as a result, numerous time-varying (random) speckle-noise patterns are produced and detected over the photo-integration time period of the image detection array in the IFD subsystem, thereby allowing these speckle-noise patterns to be temporally averaged and/or spatially averaged and the observable speckle-noise pattern reduced.

20 72. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein temporal phase modulation techniques which can be used to carry out the third generalized method include, for example: an optically-reflective cavity (i.e. etalon device) affixed to external portion of each VLD; a phase-only LCD temporal intensity modulation panel; and fiber optical arrays.

25 73. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the planar laser illumination beam is temporal phase modulated prior to target object illumination employing photon trapping, delaying and releasing principles within an optically reflective

cavity (i.e. etalon) externally affixed to each visible laser diode within the planar laser illumination array.

74. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the planar laser illumination (PLIB) is temporal phase modulated using a phase-only type LCD-based phase modulation panel prior to target object illumination.

75. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the planar laser illumination beam (PLIB) is temporal phase modulated using a high-density fiber-optic array prior to target object illumination.

76. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, based on reducing the temporal coherence of the planar laser illumination beam before it illuminates the target object by applying temporal frequency modulation techniques during the transmission of the PLIB towards the target.

77. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, based on the principle of temporal frequency modulating the transmitted planar laser illumination beam (PLIB) prior to illuminating a target object (e.g. package) therewith so that the object is illuminated with a spatially coherent-reduced planar laser beam and, as a result, numerous substantially different time-varying speckle-noise patterns are produced and detected over the photo-integration time period of the image detection array (in the IFD subsystem), thereby allowing these speckle-noise patterns to be temporally averaged and possibly spatially averaged over the photo-integration time period and the RMS power of observable speckle-noise pattern reduced.

78. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the method involves modulating the temporal frequency of the composite-type "transmitted" planar laser illumination beam (PLIB) prior to illuminating an object (e.g. package) therewith so that the object is illuminated with a temporally coherent-reduced laser beam and, as a result, numerous time-varying (random) speckle-noise patterns are produced and detected over the

photo-integration time period of the image detection array in the IFD subsystem, thereby allowing these speckle-noise patterns to be temporally averaged and/or spatially averaged and the observable speckle-noise pattern reduced.

5           79.    A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein techniques which can be used to carry out the third generalized method include, for example: junction-current control techniques for periodically inducing VLDs into a mode of frequency hopping, using thermal feedback; and multi-mode visible laser diodes (VLDs) operated just above their  
10           lasing threshold.

15           80.    A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the planar laser illumination beam is temporal frequency modulated prior to target object illumination employing drive-current modulated visible laser diodes (VLDs) into modes of frequency hopping and the like.

20           81.    A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the planar laser illumination beam is temporal frequency modulated prior to target object illumination employing multi-mode visible laser diodes (VLDs) operated just above their lasing threshold.

25           82.    A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the spatial intensity modulation techniques that can be used to carry out the method include, for example: mechanisms for moving the relative position/motion of a spatial intensity modulation array (e.g. screen) relative to a cylindrical lens array and/or a laser diode array, including reciprocating a pair of rectilinear spatial intensity modulation arrays relative to each other, as well as rotating a spatial intensity modulation array ring structure about each PLIM employed  
30           in the PLIIM-based system; a rotating spatial intensity modulation disc; and other spatial intensity modulation devices.

35           83.    A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, based on reducing the spatial-coherence of the planar laser illumination beam before it illuminates the target object

by applying spatial intensity modulation techniques during the transmission of the PLIB towards the target.

84. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the wavefront of the transmitted planar laser illumination beam (PLIB) is spatially intensity modulated prior to illuminating a target object (e.g. package) therewith so that the object is illuminated with a spatially coherent-reduced planar laser beam and, as a result, numerous substantially different time-varying speckle-noise patterns are produced and detected over the photo-integration time period of the image detection array (in the IFD subsystem), thereby allowing these speckle-noise patterns to be temporally averaged and possibly spatially averaged over the photo-integration time period and the RMS power of observable speckle-noise pattern reduced.

85. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein spatial intensity modulation techniques can be used to carry out the fifth generalized method including, for example: a pair of comb-like spatial filter arrays reciprocated relative to each other at a high-speeds; rotating spatial filtering discs having multiple sectors with transmission apertures of varying dimensions and different light transmittivity to spatial intensity modulate the transmitted PLIB along its wavefront; a high-speed LCD-type spatial intensity modulation panel; and other spatial intensity modulation devices capable of modulating the spatial intensity along the planar extent of the PLIB wavefront.

86. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein a pair of spatial intensity modulation (SIM) panels are micro-oscillated with respect to the cylindrical lens array so as to spatial-intensity modulate the planar laser illumination beam (PLIB) prior to target object illumination.

87. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, based on reducing the spatial-coherence of the planar laser illumination beam after it illuminates the target by applying spatial intensity modulation techniques during the detection of the reflected/scattered PLIB.

88. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the method is based on spatial intensity modulating the composite-type "return" PLIB produced by the composite PLIB illuminating and reflecting and scattering off an object so that the return PLIB detected by the image detection array (in the IFD subsystem) constitutes a spatially coherent-reduced laser beam and, as a result, numerous time-varying speckle-noise patterns are detected over the photo-integration time period of the image detection array (in the IFD subsystem), thereby allowing these time-varying speckle-noise patterns to be temporally and spatially-averaged and the RMS power of the observed speckle-noise patterns reduced.

89. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein (i) the return PLIB produced by the transmitted PLIB illuminating and reflecting/scattering off an object is spatial-intensity modulated (along the dimensions of the image detection elements) according to a spatial-intensity modulation function (SIMF) so as to modulate the phase along the wavefront of the composite return PLIB and produce numerous substantially different time-varying speckle-noise patterns at the image detection array in the IFD Subsystem, and also (ii) temporally and spatially average the numerous time-varying speckle-noise patterns produced at the image detection array during the photo-integration time period thereof, thereby reducing the RMS power of the speckle-noise patterns observed at the image detection array.

90. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the composite-type "return" PLIB (produced when the transmitted PLIB illuminates and reflects and/or scatters off the target object) is spatial intensity modulated, constituting a spatially coherent-reduced laser light beam and, as a result, numerous time-varying speckle-noise patterns are detected over the photo-integration time period of the image detection array in the IFD subsystem, thereby allowing these time-varying speckle-noise patterns to be temporally and/or spatially averaged and the observable speckle-noise pattern reduced.

91. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the return planar laser illumination beam is spatial-intensity modulated prior to detection at the image detector.

92. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein spatial intensity modulation techniques which can be used to carry out the sixth generalized method include, for example: high-speed electro-optical (e.g. ferro-electric, LCD, etc.) dynamic spatial filters, located before the image detector along the optical axis of the camera subsystem; physically rotating spatial filters, and any other spatial intensity modulation element arranged before the image detector along the optical axis of the camera subsystem, through which the received PLIB beam may pass during illumination and image detection operations for spatial intensity modulation without causing optical image distortion at the image detection array.

93. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein spatial intensity modulation techniques which can be used to carry out the method include, for example: a mechanism for physically or photo-electronically rotating a spatial intensity modulator (e.g. apertures, irises, etc.) about the optical axis of the imaging lens of the camera module; and any other axially symmetric, rotating spatial intensity modulation element arranged before the entrance pupil of the camera module, through which the received PLIB beam may enter at any angle or orientation during illumination and image detection operations.

94. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, based on reducing the temporal coherence of the planar laser illumination beam after it illuminates the target by applying temporal intensity modulation techniques during the detection of the reflected/scattered PLIB.

95. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the composite-type "return" PLIB (produced when the transmitted PLIB illuminates and reflects and/or scatters off the target object) is temporal intensity modulated, constituting a temporally coherent-reduced laser beam and, as a result, numerous time-varying (random) speckle-noise patterns are detected over the photo-integration time period of the image detection array (in the IFD subsystem), thereby allowing these time-varying speckle-noise patterns to be temporally and/or spatially averaged and the observable speckle-noise pattern reduced. This method can be practiced with any of the PLIM-based systems of the present invention disclosed herein, as well as any system constructed in accordance with the general principles of the present invention.



5 96. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein temporal intensity modulation techniques which can be used to carry out the method include, for example: high-speed temporal modulators such as electro-optical shutters, pupils, and stops, located along the optical path of the composite return PLIB focused by the IFD subsystem; etc.

10 97. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the return planar laser illumination beam is temporal intensity modulated prior to image detection by employing high-speed light gating/switching principles.

15 98. A planar laser illumination and imaging module which employs a planar laser illumination array (PLIA) comprising a plurality of visible laser diodes having a plurality of different characteristic wavelengths residing within different portions of the visible band.

20 99. A planar laser illumination and imaging module (PLIIM), wherein the visible laser diodes within the PLIA thereof are spatially arranged so that the spectral components of each neighboring visible laser diode (VLD) spatially overlap and each portion of the composite PLIB along its planar extent contains a spectrum of different characteristic wavelengths, thereby imparting multi-color illumination characteristics to the composite PLIB.

25 100. A PLIIM, wherein the multi-color illumination characteristics of the composite PLIB reduce the temporal coherence of the laser illumination sources in the PLIA, thereby reducing the RMS power of the speckle-noise pattern observed at the image detection array of the PLIIM.

30 101. A planar laser illumination and imaging module (PLIIM) which employs a planar laser illumination array (PLIA) comprising a plurality of visible laser diodes (VLDs) which exhibit high "mode-hopping" spectral characteristics which cooperate on the time domain to reduce the temporal coherence of the laser illumination sources operating in the PLIA and produce numerous substantially different time-varying speckle-noise patterns during each photo-integration time period, thereby reducing the RMS power of the speckle-noise pattern observed at the image detection array in the PLIIM.



5 102. A planar laser illumination and imaging module (PLIIM) which employs a planar laser illumination array (PLIA) comprising a plurality of visible laser diodes (VLDs) which are "thermally-driven" to exhibit high "mode-hopping" spectral characteristics which cooperate on the time domain to reduce the temporal coherence of the laser illumination sources operating in the PLIA, and thereby reduce the speckle noise pattern observed at the image detection array in the PLIIM accordance with the principles of the present invention.

10 103. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, employing linear (or area) electronic image detection arrays having elongated image detection elements with a high height-to-width (h/w) aspect ratio.

15 104. A method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, employing linear (or area) electronic image detection arrays having vertically-elongated image detection elements, i.e. having a high height-to-width (H/W) aspect ratio.

20 105. A PLIIM-based system with an integrated speckle-pattern noise reduction subsystem, wherein a micro-oscillating cylindrical lens array micro-oscillates a planar laser illumination beam (PLIB) laterally along its planar extent to produce spatial-incoherent PLIB components and optically combines and projects said spatially-incoherent PLIB components onto the same points on the surface of an object to be illuminated, and wherein a micro-oscillating light reflecting structure micro-oscillates the PLB components transversely along the direction orthogonal to said planar extent, and a linear (1D) image detection array with vertically-elongated image detection elements detects time-varying speckle-noise patterns produced by the spatially-incoherent components reflected/scattered off the illuminated object.

25 30 35 106. A PLIIM-based system with an integrated speckle-pattern noise reduction subsystem, wherein a first micro-oscillating light reflective element micro-oscillates a planar laser illumination beam (PLIB) laterally along its planar extent to produce spatially-incoherent PLIB components, a second micro-oscillating light reflecting element micro-oscillates the spatially-incoherent PLIB components transversely along the direction orthogonal to said planar extent, and wherein a stationary cylindrical lens array optically combines and projects said spatially-incoherent PLIB components onto the same points on the surface of an object to be illuminated, and a linear (1D) image detection array with vertically-elongated image

detection elements detects time-varying speckle-noise patterns produced by the spatially incoherent components reflected/scattered off the illuminated object.

5 107. A PLIIM-based system with an integrated speckle-pattern noise reduction subsystem, wherein an acousto-optic Bragg cell micro-oscillates a planar laser illumination beam (PLIB) laterally along its planar extent to produce spatially-incoherent PLIB components, a stationary cylindrical lens array optically combines and projects said spatially-incoherent PLIB components onto the same points on the surface of an object to be illuminated, and wherein a micro-oscillating light reflecting structure micro-oscillates the spatially-incoherent PLIB components transversely along the direction orthogonal to said planar extent, and a linear (1D) image detection array with vertically-elongated image detection elements detects time-varying speckle-noise patterns produced by spatially incoherent PLIB components reflected/scattered off the illuminated object.

10 15 20 108. A PLIIM-based system with an integrated speckle-pattern noise reduction subsystem, wherein a high-resolution deformable mirror (DM) structure micro-oscillates a planar laser illumination beam (PLIB) laterally along its planar extent to produce spatially-incoherent PLIB components, a micro-oscillating light reflecting element micro-oscillates the spatially-incoherent PLIB components transversely along the direction orthogonal to said planar extent, and wherein a stationary cylindrical lens array optically combines and projects the spatially-incoherent PLIB components onto the same points on the surface of an object to be illuminated, and a linear (1D) image detection array with vertically-elongated image detection elements detects time-varying speckle-noise patterns produced by said spatially incoherent PLIB components reflected/scattered off the illuminated object.

25 30 35 109. A PLIM-based system with an integrated speckle-pattern noise reduction subsystem, wherein a micro-oscillating cylindrical lens array micro-oscillates a planar laser illumination beam (PLIB) laterally along its planar extent to produce spatially-incoherent PLIB components which are optically combined and projected onto the same points on the surface of an object to be illuminated, and a micro-oscillating light reflective structure micro-oscillates the spatially-incoherent PLIB components transversely along the direction orthogonal to said planar extent as well as the field of view (FOV) of a linear (1D) image detection array having vertically-elongated image detection elements, whereby said linear CCD detection array detects time-varying speckle-noise patterns produced by the spatially incoherent PLIB components reflected/scattered off the illuminated object.

110. A PLIIM-based system with an integrated speckle-pattern noise reduction subsystem, wherein a micro-oscillating cylindrical lens array micro-oscillates a planar laser illumination beam (PLIB) laterally along its planar extent and produces spatially-incoherent PLIB components which are optically combined and project onto the same points of an object to be illuminated, a micro-oscillating light reflective structure micro-oscillates transversely along the direction orthogonal to said planar extent, both PLIB and the field of view (FOV) of a linear (1D) image detection array having vertically-elongated image detection elements, and a PLIB/FOV folding mirror projects the micro-oscillated PLIB and fov towards said object, whereby said linear image detection array detects time-varying speckle-noise patterns produced by the spatially incoherent PLIB components reflected/scattered off the illuminated object.

111. A PLIIM-based system with an integrated speckle-pattern noise reduction subsystem, wherein a phase-only LCD-based phase modulation panel micro-oscillates a planar laser illumination beam (PLIB) laterally along its planar extent and produces spatially-incoherent PLIB components, a stationary cylindrical lens array optically combines and projects the spatially-incoherent PLIB components onto the same points on the surface of an object to be illuminated, and wherein a micro-oscillating light reflecting structure micro-oscillates the spatially-incoherent PLIB components transversely along the direction orthogonal to said planar extent, and a linear (1D) CCD image detection array with vertically-elongated image detection elements detects time-varying speckle-noise patterns produced by the spatially incoherent PLIB components reflected/scattered off the illuminated object.

112. A PLIIM-based system with an integrated speckle-pattern noise reduction subsystem, wherein a multi-faceted cylindrical lens array structure rotating about its longitudinal axis within each PLIM micro-oscillates a planar laser illumination beam (PLIB) laterally along its planar extent and produces spatially-incoherent PLIB components therealong, a stationary cylindrical lens array optically combines and projects the spatially-incoherent PLIB components onto the same points on the surface of an object to be illuminated, and wherein a micro-oscillating light reflecting structure micro-oscillates the spatially-incoherent PLIB components transversely along the direction orthogonal to said planar extent, and a linear (1D) image detection array with vertically-elongated image detection elements detects time-varying speckle-noise patterns produced by the spatially incoherent PLIB components reflected/scattered off the illuminated object.

113. A PLIIM-based system with an integrated speckle-pattern noise reduction subsystem, wherein a multi-faceted cylindrical lens array structure within each PLIM rotates about its longitudinal and transverse axes, micro-oscillates a planar laser illumination beam (PLIB) laterally along its planar extent as well as transversely along the direction orthogonal to said planar extent, and produces spatially-incoherent PLIB components along said orthogonal directions, and wherein a stationary cylindrical lens array optically combines and projects the spatially-incoherent PLIB components onto the same points on the surface of an object to be illuminated, and a linear (1D) image detection array with vertically-elongated image detection elements detects time-varying speckle-noise patterns produced by the spatially incoherent PLIB components reflected/scattered off the illuminated object.

114. A PLIIM-based system with an integrated hybrid-type speckle-pattern noise reduction subsystem, wherein a high-speed temporal intensity modulation panel temporal intensity modulates a planar laser illumination beam (PLIB) to produce temporally-incoherent PLIB components along its planar extent, a stationary cylindrical lens array optically combines and projects the temporally-incoherent PLIB components onto the same points on the surface of an object to be illuminated, and wherein a micro-oscillating light reflecting element micro-oscillates the PLIB transversely along the direction orthogonal to said planar extent to produce spatially-incoherent PLIB components along said transverse direction, and a linear (1D) image detection array with vertically-elongated image detection elements detects time-varying speckle-noise patterns produced by the temporally and spatially incoherent PLIB components reflected/scattered off the illuminated object.

115. A PLIIM-based system with an integrated hybrid-type speckle-pattern noise reduction subsystem, wherein an optically-reflective cavity (i.e. etalon) externally attached to each VLD in the system temporal phase modulates a planar laser illumination beam (PLIB) to produce temporally-incoherent PLIB components along its planar extent, a stationary cylindrical lens array optically combines and projects the temporally-incoherent PLIB components onto the same points on the surface of an object to be illuminated, and wherein a micro-oscillating light reflecting element micro-oscillates the PLIB transversely along the direction orthogonal to said planar extent to produce spatially-incoherent PLIB components along said transverse direction, and a linear (1D) image detection array with vertically-elongated image detection elements detects time-varying speckle-noise patterns produced by the temporally and spatially incoherent PLIB components reflected/scattered off the illuminated object.

116. A PLIIM-based system with an integrated hybrid-type speckle-pattern noise reduction subsystem, wherein each visible mode locked laser diode (MLLD) employed in the plim of the system generates a high-speed pulsed (i.e. temporal intensity modulated) planar laser illumination beam (PLIB) having temporally-incoherent PLIB components along its planar extent, a stationary cylindrical lens array optically combines and projects the temporally-incoherent PLIB components onto the same points on the surface of an object to be illuminated, and wherein a micro-oscillating light reflecting element micro-oscillates PLIB transversely along the direction orthogonal to said planar extent to produce spatially-incoherent PLIB components along said transverse direction, and a linear (1D) image detection array with vertically-elongated image detection elements detects time-varying speckle-noise patterns produced by the temporally and spatially incoherent PLIB components reflected/scattered off the illuminated object.

117. A PLIIM-based system with an integrated hybrid-type speckle-pattern noise reduction subsystem, wherein the visible laser diode (VLD) employed in each PLIM of the system is continually operated in a frequency-hopping mode so as to temporal frequency modulate the planar laser illumination beam (PLIB) and produce temporally-incoherent PLIB components along its planar extent, a stationary cylindrical lens array optically combines and projects the temporally-incoherent PLIB components onto the same points on the surface of an object to be illuminated, and wherein a micro-oscillating light reflecting element micro-oscillates the PLIB transversely along the direction orthogonal to said planar extent and produces spatially-incoherent PLIB components along said transverse direction, and a linear (1D) image detection array with vertically-elongated image detection elements detects time-varying speckle-noise patterns produced by the temporally and spatial incoherent PLIB components reflected/scattered off the illuminated object.

118. A PLIIM-based system with an integrated hybrid-type speckle-pattern noise reduction subsystem, wherein a pair of micro-oscillating spatial intensity modulation panels modulate the spatial intensity along the wavefront of a planar laser illumination beam (PLIB) and produce spatially-incoherent PLIB components along its planar extent, a stationary cylindrical lens array optically combines and projects the spatially-incoherent PLIB components onto the same points on the surface of an object to be illuminated, and wherein a micro-oscillating light reflective structure micro-oscillates said PLIB transversely along the direction orthogonal to said planar extent and produces spatially-incoherent PLIB components along said transverse direction, and a linear (1D) image detection array having vertically-elongated image

detection elements detects time-varying speckle-noise patterns produced by the spatially incoherent PLIB components reflected/scattered off the illuminated object.

5 119. A method of and apparatus for mounting a linear image sensor chip within a PLIIM-based system to prevent misalignment between the field of view (FOV) of said linear image sensor chip and the planar laser illumination beam (PLIB) used therewith, in response to thermal expansion or cycling within said PLIIM-based system.

10 120. A method of and apparatus for mounting a linear image sensor chip relative to a heat sinking structure to prevent any misalignment between the field of view (FOV) of the image sensor chip and the PLIA produced by the PLIA within the camera subsystem, thereby improving the performance of the PLIIM-based system during planar laser illumination and imaging operations.

15 121. A camera subsystem wherein the linear image sensor chip employed in the camera is rigidly mounted to the camera body of a PLIIM-based system via a novel image sensor mounting mechanism which prevents any significant misalignment between the field of view (FOV) of the image detection elements on the linear image sensor chip and the planar laser illumination beam (PLIB) produced by the PLIA used to illuminate the FOV thereof within the IFD module (i.e. camera subsystem).

20 122. A method of and apparatus for automatically controlling the output optical power of the VLDs in the planar laser illumination array of a PLIIM-based system in response to the detected speed of objects transported along a conveyor belt, so that each digital image of each object captured by the PLIIM-based system has a substantially uniform "white" level, regardless of conveyor belt speed, thereby simplifying the software-based image processing operations which need to subsequently carried out by the image processing computer subsystem.

25 30 123. A method of and apparatus for automatically controlling the output optical power of the VLDs in the planar laser illumination array of a PLIIM-based system, wherein a camera control computer in the PLIIM-based system performs the following operations: (i) computes the optical power (measured in milliwatts) which each VLD in the PLIIM-based system must produce in order that each digital image captured by the PLIIM-based system will have substantially the same "white" level, regardless of conveyor belt speed; and (2) transmits

the computed VLD optical power value(s) to the micro-controller associated with each PLIA in the PLIIM-based system.

5 124. A PLIIM-based systems embodying speckle-pattern noise reduction subsystems comprising a linear (1D) image sensor with vertically-elongated image detection elements, a pair of planar laser illumination modules (PLIMs), and a 2-D PLIB micro-oscillation mechanism arranged therewith for enabling both lateral and transverse micro-movement of the planar laser illumination beam (PLIB).

10 125. PLIIM-based systems embodying speckle-pattern noise reduction subsystems comprising a linear (1D) image sensor with vertically-elongated image detection elements, a pair of planar laser illumination modules (PLIMs), and a 2-D PLIB micro-oscillation mechanism arranged therewith for enabling both lateral and transverse micro-movement of the planar laser illumination beam (PLIB).

15 126. A PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a 2-D PLIB micro-oscillation mechanism arranged with each PLIM, and employing a micro-oscillating cylindrical lens array and a micro-oscillating PLIB reflecting mirror configured together as an optical assembly for the purpose of micro-oscillating the PLIB laterally along its planar extent as well as transversely along the direction orthogonal thereto, so  
20 that during illumination operations, the PLIB is spatial phase modulated along the planar extent thereof as well as along the direction orthogonal thereto, causing the phase along the wavefront of each transmitted PLIB to be modulated in two orthogonal dimensions and numerous substantially different time-varying speckle-noise patterns to be produced at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image  
25 detection array.

30 127. A PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an  
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optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a 2-D PLIB micro-oscillation mechanism arranged with each PLIM, and employing a stationary PLIB folding mirror, a micro-oscillating PLIB reflecting element, and a stationary cylindrical lens array configured together as an optical assembly as shown for the purpose of micro-oscillating the PLIB laterally along its planar extent as well as transversely along the direction orthogonal thereto, so that during illumination operations, the PLIB transmitted from each PLIM is spatial phase modulated along the planar extent thereof as well as along the direction orthogonal thereto, causing the phase along the wavefront of each transmitted PLIB to be modulated in two orthogonal dimensions and numerous substantially different time-varying speckle-noise patterns to be produced at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

128. A PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a 2-D PLIB micro-oscillation mechanism arranged with each PLIM, and employing a micro-oscillating cylindrical lens array and a micro-oscillating PLIB reflecting element configured together as shown as an optical assembly for the purpose of micro-oscillating the PLIB laterally along its planar extent as well as transversely along the direction orthogonal thereto, so that during illumination operations, the PLIB transmitted from each PLIM is spatial phase modulated along the planar extent thereof as well as along the direction orthogonal (i.e. transverse) thereto, causing the phase along the wavefront of each transmitted PLIB to be modulated in two orthogonal dimensions and numerous substantially different time-varying speckle-noise patterns to be produced at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.



129. A PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a 2-D PLIB micro-oscillation mechanism arranged with each PLIM, and employing a micro-oscillating high-resolution deformable mirror structure, a stationary PLIB reflecting element and a stationary cylindrical lens array configured together as an optical assembly as shown for the purpose of micro-oscillating the PLIB laterally along its planar extent as well as transversely along the direction orthogonal thereto, so that during illumination operation, the PLIB transmitted from each PLIM is spatial phase modulated along the planar extent thereof as well as along the direction orthogonal (i.e. transverse) thereto, causing the phase along the wavefront of each transmitted PLIB to be modulated in two orthogonal dimensions and numerous substantially different time-varying speckle-noise patterns to be produced at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

130. A PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a 2-D PLIB micro-oscillation mechanism arranged with each PLIM, and employing a micro-oscillating cylindrical lens array structure for micro-oscillating the PLIB laterally along its planar extend, a micro-oscillating PLIB/FOV refraction element for micro-oscillating the PLIB and the field of view (FOV) of the linear image sensor transversely along the direction orthogonal to the planar extent of the PLIB, and a stationary PLIB/FOV folding mirror configured together as an optical assembly as shown for the purpose of micro-oscillating the PLIB laterally along its planar extent while micro-oscillating both the PLIB and FOV of the linear image sensor transversely along the direction orthogonal thereto, so that during illumination operation, the PLIB transmitted from each PLIM is spatial phase modulated along the planar extent thereof as well as along the direction orthogonal (i.e. transverse) thereto, causing the phase along the wavefront of each transmitted PLIB to be modulated in two

orthogonal dimensions and numerous substantially different time-varying speckle-noise patterns to be produced at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

131. A PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a 2-D PLIB micro-oscillation mechanism arranged with each PLIM, and employing a micro-oscillating cylindrical lens array structure for micro-oscillating the PLIB laterally along its planar extend, a micro-oscillating PLIB/FOV reflection element for micro-oscillating the PLIB and the field-of-view (FOV) of the linear image sensor transversely along the direction orthogonal to the planar extent of the PLIB, and a stationary PLIB/FOV folding mirror configured together as an optical assembly as shown for the purpose of micro-oscillating the PLIB laterally along its planar extent while micro-oscillating both the PLIB and FOV of the linear image sensor transversely along the direction orthogonal thereto, so that during illumination operation, the PLIB transmitted from each PLIM is spatial phase modulated along the planar extent thereof as well as along the direction orthogonal thereto, causing the phase along the wavefront of each transmitted PLIB to be modulated in two orthogonal dimensions and numerous substantially different time-varying speckle-noise patterns to be produced at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

132. A PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a 2-D PLIB micro-oscillation mechanism arranged with each PLIM, and

employing a phase-only LCD phase modulation panel, a stationary cylindrical lens array, and a micro-oscillating PLIB reflection element, configured together as an optical assembly as shown for the purpose of micro-oscillating the PLIB laterally along its planar extent while micro-oscillating the PLIB transversely along the direction orthogonal thereto, so that during illumination operation, the PLIB transmitted from each PLIM is spatial phase modulated along the planar extent thereof as well as along the direction orthogonal (i.e. transverse) thereto, causing the phase along the wavefront of each transmitted PLIB to be modulated in two orthogonal dimensions and numerous substantially different time-varying speckle-noise patterns to be produced at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

133. A PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a 2-D PLIB micro-oscillation mechanism arranged with each PLIM, and employing a micro-oscillating multi-faceted cylindrical lens array structure, a stationary cylindrical lens array, and a micro-oscillating PLIB reflection element configured together as an optical assembly as shown, for the purpose of micro-oscillating the PLIB laterally along its planar extent while micro-oscillating the PLIB transversely along the direction orthogonal thereto, so that during illumination operation, the PLIB transmitted from each PLIM is spatial phase modulated along the planar extent thereof as well as along the direction orthogonal thereto, causing the phase along the wavefront of each transmitted PLIB to be modulated in two orthogonal dimensions and numerous substantially different time-varying speckle-noise patterns to be produced at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

134. A PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an

optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a 2-D PLIB micro-oscillation mechanism arranged with each PLIM, and employing a micro-oscillating multi-faceted cylindrical lens array structure (adapted for micro-oscillation about the optical axis of the VLD's laser illumination beam and along the planar extent of the PLIB) and a stationary cylindrical lens array, configured together as an optical assembly as shown, for the purpose of micro-oscillating the PLIB laterally along its planar extent while micro-oscillating the PLIB transversely along the direction orthogonal thereto, so that during illumination operation, the PLIB transmitted from each PLIM is spatial phase modulated along the planar extent thereof as well as along the direction orthogonal thereto, causing the phase along the wavefront of each transmitted PLIB to be modulated in two orthogonal dimensions and numerous substantially different time-varying speckle-noise patterns to be produced at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

135. A PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a hybrid-type PLIB modulation mechanism arranged with each PLIM, and employing a temporal-intensity modulation panel, a stationary cylindrical lens array, and a micro-oscillating PLIB reflection element configured together as an optical assembly as shown, for the purpose of temporal intensity modulating the PLIB uniformly along its planar extent while micro-oscillating the PLIB transversely along the direction orthogonal thereto, so that during illumination operations, the PLIB transmitted from each PLIM is spatial phase modulated along the planar extent thereof during micro-oscillation along the direction orthogonal thereto, thereby producing numerous substantially different time-varying speckle-noise patterns at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of

the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

136. A PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a hybrid-type PLIB modulation mechanism arranged with each PLIM, and employing a temporal-intensity modulation panel, a stationary cylindrical lens array, and a micro-oscillating PLIB reflection element configured together as an optical assembly as shown, for the purpose of temporal intensity modulating the PLIB uniformly along its planar extent while micro-oscillating the PLIB transversely along the direction orthogonal thereto, so that during illumination operations, the PLIB transmitted from each PLIM is spatial phase modulated along the planar extent thereof during micro-oscillation along the direction orthogonal thereto, thereby producing numerous substantially different time-varying speckle-noise patterns at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

137. A PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a hybrid-type PLIB modulation mechanism arranged with each PLIM, and employing a visible mode-locked laser diode (MLLD), a stationary cylindrical lens array, and a micro-oscillating PLIB reflection element configured together as an optical assembly as shown, for the purpose of producing a temporal intensity modulated PLIB while micro-oscillating the PLIB transversely along the direction orthogonal to its planar extent, so that during illumination operations, the PLIB transmitted from each PLIM is spatial phase modulated along the planar extent thereof during micro-oscillation along the direction orthogonal thereto, thereby producing numerous substantially different time-varying speckle-noise patterns at the vertically-elongated image detection elements of the IFD Subsystem during the photo-

integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

138. A PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a hybrid-type PLIB modulation mechanism arranged with each PLIM, and employing a visible laser diode (VLD) driven into a high-speed frequency hopping mode, a stationary cylindrical lens array, and a micro-oscillating PLIB reflection element configured together as an optical assembly as shown, for the purpose of producing a temporal frequency modulated PLIB while micro-oscillating the PLIB transversely along the direction orthogonal to its planar extent, so that during illumination operations, the PLIB transmitted from each PLIM is spatial phase modulated along the planar extent thereof during micro-oscillation along the direction orthogonal thereto, thereby producing numerous substantially different time-varying speckle-noise patterns at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

139. A PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a hybrid-type PLIB modulation mechanism arranged with each PLIM, and employing a micro-oscillating spatial intensity modulation array, a stationary cylindrical lens array, and a micro-oscillating PLIB reflection element configured together as an optical assembly as shown, for the purpose of producing a spatial intensity modulated PLIB while micro-oscillating the PLIB transversely along the direction orthogonal to its planar extent, so that during illumination operations, the PLIB transmitted from each PLIM is spatial phase modulated along the planar extent thereof during micro-oscillation along the direction



orthogonal thereto, thereby producing numerous substantially different time-varying speckle-noise patterns at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

140. A PLIIM-based hand-supportable linear imager which contains within its housing, a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA and a 1-D (i.e. linear) image detection array with vertically-elongated image detection elements and configured within an optical assembly that operates in accordance with the first generalized method of speckle-pattern noise reduction of the present invention, and which also has integrated with its housing, a LCD display panel for displaying images captured by said engine and information provided by a host computer system or other information supplying device, and a manual data entry keypad for manually entering data into the imager during diverse types of information-related transactions supported by the PLIIM-based hand-supportable imager.

141. A manually-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and fixed focal length/fixed focal distance image formation optics, (ii) a manually-actuated trigger switch for manually activating the planar laser illumination arrays (driven by a set of VLD driver circuits), the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, upon manual activation of the trigger switch, and capturing images of objects (i.e. bearing bar code symbols and other graphical indicia) through the fixed focal length/fixed focal distance image formation optics, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

142. An automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and fixed focal length/fixed focal distance image formation optics, (ii) an IR-based object detection subsystem within its hand-supportable housing for automatically activating upon detection of an object in its IR-based object detection field, the planar laser illumination arrays (driven by a set of VLD

driver circuits), the linear-type image formation and detection (IFD) module, as well as the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, (ii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

143. An automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and fixed focal length/fixed focal distance image formation optics, (ii) a laser-based object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination arrays into a full-power mode of operation, the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, upon automatic detection of an object in its laser-based object detection field, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame; and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

144. An automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and fixed focal length/fixed focal distance image formation optics, (ii) an ambient-light driven object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination arrays (driven by a set of VLD driver circuits), the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, upon automatic detection of an object via ambient-light detected by object detection field enabled by the image sensor within the IFD module, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

145. An automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear



image detection array with vertically-elongated image detection elements and fixed focal length/fixed focal distance image formation optics, (ii) an automatic bar code symbol detection subsystem within its hand-supportable housing for automatically activating the image processing computer for decode-processing upon automatic detection of an bar code symbol within its bar code symbol detection field enabled by the image sensor within the IFD module, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

146. A manually-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and fixed focal length/variable focal distance image formation optics, (ii) a manually-actuated trigger switch for manually activating the planar laser illumination arrays (driven by a set of VLD driver circuits), the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, upon manual activation of the trigger switch, and capturing images of objects (i.e. bearing bar code symbols and other graphical indicia) through the fixed focal length/fixed focal distance image formation optics, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

147. An automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and fixed focal length/variable focal distance image formation optics, (ii) an IR-based object detection subsystem within its hand-supportable housing for automatically activating upon detection of an object in its IR-based object detection field, the planar laser illumination arrays (driven by a set of VLD driver circuits), the linear-type image formation and detection (IFD) module, as well as the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, (ii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

148. An automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and fixed focal length/variable focal distance image formation optics, (ii) a laser-based object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination arrays into a full-power mode of operation, the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, upon automatic detection of an object in its laser-based object detection field, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

149. An automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and fixed focal length/variable focal distance image formation optics, (ii) an ambient-light driven object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination arrays (driven by a set of VLD driver circuits), the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, upon automatic detection of an object via ambient-light detected by object detection field enabled by the image sensor within the IFD module, and (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame.

150. An automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and fixed focal length/variable focal distance image formation optics, (ii) an automatic bar code symbol detection subsystem within its hand-supportable housing for automatically activating the image processing computer for decode-processing upon automatic detection of an bar code symbol within its bar code symbol detection field enabled by the image sensor within the IFD module, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame, and (iv) a

LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

5 151. A manually-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and variable focal length/variable focal distance image formation optics, (ii) a manually-actuated trigger switch for manually activating the planar laser illumination arrays (driven by a set of VLD driver circuits), the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, upon manual activation of the trigger switch, and capturing images of objects (i.e. bearing bar code symbols and other graphical indicia) through the fixed focal length/fixed focal distance image formation optics, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

15 20 25 152. An automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and variable focal length/variable focal distance image formation optics, (ii) an IR-based object detection subsystem within its hand-supportable housing for automatically activating upon detection of an object in its IR-based object detection field, the planar laser illumination arrays (driven by a set of VLD driver circuits), the linear-type image formation and detection (IFD) module, as well as the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, (ii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

30 35 153. An automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and variable focal length/variable focal distance image formation optics, (ii) a laser-based object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination arrays into a full-power mode of operation, the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, upon automatic detection of an object in

its laser-based object detection field, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

154. An automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and variable focal length/variable focal distance image formation optics, (ii) an ambient-light driven object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination arrays (driven by a set of VLD driver circuits), the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, upon automatic detection of an object via ambient-light detected by object detection field enabled by the image sensor within the IFD module, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

155. An automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and variable focal length/variable focal distance image formation optics, (ii) an automatic bar code symbol detection subsystem within its hand-supportable housing for automatically activating the image processing computer for decode-processing upon automatic detection of an bar code symbol within its bar code symbol detection field enabled by the image sensor within the IFD module, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

156. A PLIIM-based image capture and processing engines with linear image detection array having vertically-elongated image detection elements and an integrated despeckling mechanism.

157. A PLIIM-based image capture and processing engine for use in a hand-supportable imager.

158. A PLIIM-based image capture and processing engine for use in the hand-supportable imagers, presentation scanners, and the like, comprising PLIAs, and IFD (i.e. camera) subsystem and associated optical components mounted on an optical-bench/multi-layer PC board, contained between the upper and lower portions of the engine housing.

159. A PLIIM-based hand-supportable linear imager which contains within its housing, a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA and a linear image detection array with vertically-elongated image detection elements configured within an optical assembly that provides a despeckling mechanism which operates in accordance with the first generalized method of speckle-pattern noise reduction.

160. A PLIIM-based hand-supportable linear imager which contains within its housing, a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA and a linear image detection array having vertically-elongated image detection elements configured within an optical assembly which provides a despeckling mechanism that operates in accordance with the first generalized method of speckle-pattern noise reduction.

161. A PLIIM-based image capture and processing engine for use in the hand-supportable imagers, presentation scanners, and the like, comprising a dual-VLD PLIA and a linear image detection array having vertically-elongated image detection elements configured within an optical assembly which employs high-resolution deformable mirror (DM) structure which provides a despeckling mechanism that operates in accordance with the first generalized method of speckle-pattern noise reduction.

162. A PLIIM-based image capture and processing engine for use in the hand-supportable imagers, presentation scanners, and the like, comprising a dual-VLD PLIA and a linear image detection array having vertically-elongated image detection elements configured within an optical assembly that employs a high-resolution phase-only LCD-based phase modulation panel which provides a despeckling mechanism that operates in accordance with the first generalized method of speckle-pattern noise reduction.

163. A PLIIM-based image capture and processing engine for use in the hand-supportable imagers, presentation scanners, and the like, comprising a dual-VLD PLIA and a

linear image detection array having vertically-elongated image detection elements configured within an optical assembly that employs a rotating multi-faceted cylindrical lens array structure which provides a despeckling mechanism that operates in accordance with the first generalized method of speckle-pattern noise reduction.

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164. A PLIIM-based image capture and processing engine for use in the hand-supportable imagers, presentation scanners, and the like, comprising a dual-VLD PLIA and a linear image detection array having vertically-elongated image detection elements configured within an optical assembly that employs a high-speed temporal intensity modulation panel (i.e. optical shutter) which provides a despeckling mechanism that operates in accordance with the second generalized method of speckle-pattern noise reduction.

165. A PLIIM-based image capture and processing engine for use in the hand-supportable imagers, presentation scanners, and the like, comprising a dual-VLD PLIA and a linear image detection array having vertically-elongated image detection elements configured within an optical assembly that employs visible mode-locked laser diode (MLLDs) which provide a despeckling mechanism that operates in accordance with the second method generalized method of speckle-pattern noise reduction.

166. A PLIIM-based image capture and processing engine for use in the hand-supportable imagers, presentation scanners, and the like, comprising a dual-VLD PLIA and a linear image detection array having vertically-elongated image detection elements configured within an optical assembly that employs an optically-reflective temporal phase modulating structure (i.e. etalon) which provides a despeckling mechanism that operates in accordance with the third generalized method of speckle-pattern noise reduction.

167. A PLIIM-based image capture and processing engine for use in the hand-supportable imagers, presentation scanners, and the like, comprising a dual-VLD PLIA and a linear image detection array having vertically-elongated image detection elements configured within an optical assembly that employs a pair of reciprocating spatial intensity modulation panels which provide a despeckling mechanism that operates in accordance with the fifth method generalized method of speckle-pattern noise reduction.

168. A PLIIM-based image capture and processing engine for use in the hand-supportable imagers, presentation scanners, and the like, comprising a dual-VLD PLIA and a linear image detection array having vertically-elongated image detection elements configured

within an optical assembly that employs spatial intensity modulation aperture which provides a despeckling mechanism that operates in accordance with the sixth method generalized method of speckle-pattern noise reduction.

5           169. A PLIIM-based image capture and processing engine for use in the hand-supportable imagers, presentation scanners, and the like, comprising a dual-VLD PLIA and a linear image detection array having vertically-elongated image detection elements configured within an optical assembly that employs a temporal intensity modulation aperture which provides a despeckling mechanism that operates in accordance with the seventh generalized method of speckle-pattern noise reduction.

10           170. A PLIIM-based hand-supportable imagers having a 2D PLIIM-based engines and an integrated despeckling mechanism

15           171. A hand-supportable imager having a housing containing a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA, and a 2-D (area-type) image detection array configured within an optical assembly that employs a micro-oscillating cylindrical lens array which provides a despeckling mechanism that operates in accordance with the first generalized method of speckle-pattern noise reduction, and which also has integrated with its housing, a LCD display panel for displaying images captured by said engine and information provided by a host computer system or other information supplying device, and a manual data entry keypad for manually entering data into the imager during diverse types of information-related transactions supported by the PLIIM-based hand-supportable imager.

25           172. A hand-supportable imager having a housing containing a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA and an area image detection array configured within an optical assembly which employs a micro-oscillating light reflective element that provides a despeckling mechanism that operates in accordance with the first generalized method of speckle-pattern noise reduction, and which also has integrated with its housing, a LCD display panel for displaying images captured by said engine and information provided by a host computer system or other information supplying device, and a manual data entry keypad for manually entering data into the imager during diverse types of information-related transactions supported by the PLIIM-based hand-supportable imager.



5 173. A hand-supportable imager having a housing containing a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA and a 2-D image detection array configured within an optical assembly that employs an acousto-electric Bragg cell structure which provides a despeckling mechanism that operates in accordance with the first generalized method of speckle-pattern noise reduction, and which also has integrated with its housing, a LCD display panel for displaying images captured by said engine and information provided by a host computer system or other information supplying device, and a manual data entry keypad for manually entering data into the imager during diverse types of information-related transactions supported by the PLIIM-based hand-supportable imager.

10 174. A hand-supportable imager having a housing containing a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA and a 2-D image detection array configured within an optical assembly that employs a high spatial-resolution piezo-electric driven deformable mirror (DM) structure which provides a despeckling mechanism that operates in accordance with the first generalized method of speckle-pattern noise reduction, and which also has integrated with its housing, a LCD display panel for displaying images captured by said engine and information provided by a host computer system or other information supplying device, and a manual data entry keypad for manually entering data into the imager during diverse types of information-related transactions supported by the PLIIM-based hand-supportable imager.

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20 175. A hand-supportable imager having a housing containing a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA and a 2-D image detection array configured within an optical assembly that employs a spatial-only liquid crystal display (PO-LCD) type spatial phase modulation panel which provides a despeckling mechanism that operates in accordance with the first generalized method of speckle-pattern noise reduction, and which also has integrated with its housing, a LCD display panel for displaying images captured by said engine and information provided by a host computer system or other information supplying device, and a manual data entry keypad for manually entering data into the imager during diverse types of information-related transactions supported by the PLIIM-based hand-supportable imager.

25 176. A hand-supportable imager having a housing containing a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA and a 2-D image detection array configured within an optical assembly that employs a visible mode locked laser diode (MLLD) which provides a despeckling mechanism that operates in accordance with the second

5 generalized method of speckle-pattern noise reduction, and which also has integrated with its housing, a LCD display panel for displaying images captured by said engine and information provided by a host computer system or other information supplying device, and a manual data entry keypad for manually entering data into the imager during diverse types of information-related transactions supported by the PLIIM-based hand-supportable imager.

10 177. A hand-supportable imager having a housing containing a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA and a 2-D image detection array configured within an optical assembly that employs an electrically-passive optically-reflective cavity (i.e. etalon) which provides a despeckling mechanism that operates in accordance with the third method generalized method of speckle-pattern noise reduction, and which also has integrated with its housing, a LCD display panel for displaying images captured by said engine and information provided by a host computer system or other information supplying device, and a manual data entry keypad for manually entering data into the imager during diverse types of information-related transactions supported by the PLIIM-based hand-supportable imager.

15 20 25 178. A hand-supportable imager having a housing containing a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA and a 2-D image detection array configured within an optical assembly that employs a pair of micro-oscillating spatial intensity modulation panels which provide a despeckling mechanism that operates in accordance with the fifth method generalized method of speckle-pattern noise reduction, and which also has integrated with its housing, a LCD display panel for displaying images captured by said engine and information provided by a host computer system or other information supplying device, and a manual data entry keypad for manually entering data into the imager during diverse types of information-related transactions supported by the PLIIM-based hand-supportable imager.

30 35 179. A hand-supportable imager having a housing containing a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA and a 2-D image detection array configured within an optical assembly that employs a electro-optical or mechanically rotating aperture (i.e. iris) disposed before the entrance pupil of the IFD module, which provides a despeckling mechanism that operates in accordance with the sixth method generalized method of speckle-pattern noise reduction, and which also has integrated with its housing, a LCD display panel for displaying images captured by said engine and information provided by a host computer system or other information supplying device, and a manual data entry keypad

for manually entering data into the imager during diverse types of information-related transactions supported by the PLIIM-based hand-supportable imager.

180. A hand-supportable imager having a housing containing a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA and a 2-D image detection array configured within an optical assembly that employs a high-speed electro-optical shutter disposed before the entrance pupil of the IFD module, which provides a despeckling mechanism that operates in accordance with the seventh generalized method of speckle-pattern noise reduction, and which also has integrated with its housing, a LCD display panel for displaying images captured by said engine and information provided by a host computer system or other information supplying device, and a manual data entry keypad for manually entering data into the imager during diverse types of information-related transactions supported by the PLIIM-based hand-supportable imager.

181. A manually-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type (i.e. 1D) image formation and detection (IFD) module having a fixed focal length/fixed focal distance image formation optics with a field of view (FOV), (ii) a manually-actuated trigger switch for manually activating the planar laser illumination array (to producing a PLIB in coplanar arrangement with said FOV), the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, upon response to the manual activation of the trigger switch, and capturing images of objects (i.e. bearing bar code symbols and other graphical indicia) through the fixed focal length/fixed focal distance image formation optics, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

182. An automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a fixed focal length/fixed focal distance image formation optics with a field of view (FOV), (ii) an IR-based object detection subsystem within its hand-supportable housing for automatically activating upon detection of an object in its IR-based object detection field, the planar laser illumination array (to produce a PLIB in coplanar arrangement with said FOV), the linear-type image formation and detection (IFD) module, as well as the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, (ii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame, and (iii) a

LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

183. An automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a fixed focal length/fixed focal distance image formation optics with a field of view (FOV), (ii) a laser-based object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination array into a full-power mode of operation (to produce a PLIB in coplanar arrangement with said FOV), the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, in response to the automatic detection of an object in its laser-based object detection field, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame; and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

184. An automatically-activated PLIIM-based hand-supportable linear imager shown configured with (i) a linear-type image formation and detection (IFD) module having a fixed focal length/fixed focal distance image formation optics with a field of view (FOV), (ii) an ambient-light driven object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination array (to produce a PLIB in coplanar arrangement with said FOV), the area-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, upon automatic detection of an object via ambient-light detected by object detection field enabled by the image sensor within the IFD module, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system in response to decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

185. An automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a fixed focal length/fixed focal distance image formation optics with a field of view (FOV), (ii) an automatic bar code symbol detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination array (to produce a PLIB in coplanar arrangement with said FOV), the image processing computer for decode-processing in response

to the automatic detection of an bar code symbol within its bar code symbol detection field enabled by the image sensor within the IFD module, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system in response to decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

186. A manually-activated PLIIM-based hand-supportable linear imager configured with (i) a linear -type image formation and detection (IFD) module having a fixed focal length/variable focal distance image formation optics with a field of view (FOV), (ii) a manually-actuated trigger switch for manually activating the planar laser illumination (to produce a planar laser illumination beam (PLIB) in coplanar arrangement with said FOV), the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, in response to the manual activation of the trigger switch, and capturing images of objects (i.e. bearing bar code symbols and other graphical indicia) through the fixed focal length/fixed focal distance image formation optics, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

187. An automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a fixed focal length/variable focal distance image formation optics with a field of view (FOV), (ii) an IR-based object detection subsystem within its hand-supportable housing for automatically activating in response to the detection of an object in its IR-based object detection field, the planar laser illumination array (to produce a PLIB in coplanar arrangement with said FOV), the linear-type image formation and detection (IFD) module, as well as the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, (ii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system in response to decoding a bar code symbol within a captured image frame, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

188. An automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a fixed focal length/variable focal distance image formation optics with a field of view (FOV), (ii) a laser-based object detection subsystem within its hand-supportable housing for automatically

activating the planar laser illumination array into a full-power mode of operation (to produce a PLIB in coplanar arrangement with said FOV), the a linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, upon automatic detection of an object in its laser-based object detection field, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system in response to the decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

189. An automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a fixed focal length/variable focal distance image formation optics with a field of FOV, (ii) an ambient-light driven object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination array (to produce a PLIB in coplanar arrangement with said FOV), the area-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, in response to the automatic detection of an object via ambient-light detected by object detection field enabled by the image sensor within the IFD module, and (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame.

190. An automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear -type image formation and detection (IFD) module having a fixed focal length/variable focal distance image formation optics with a field of view (FOV), (ii) an automatic bar code symbol detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination array (to produce a PLIB in coplanar arrangement with said FOV), the image processing computer for decode-processing in response to the automatic detection of an bar code symbol within its bar code symbol detection field enabled by the image sensor within the IFD module, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system in response to decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

191. A manually-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a variable focal



length/variable focal distance image formation optics with a field of FOV, (ii) a manually-actuated trigger switch for manually activating the planar laser illumination array (to produce a PLIB in coplanar arrangement with said FOV), the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, in response to the manual activation of the trigger switch, and capturing images of objects (i.e. bearing bar code symbols and other graphical indicia) through the fixed focal length/fixed focal distance image formation optics, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

192. An automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a variable focal length/variable focal distance image formation optics with a field of view (FOV), (ii) an IR-based object detection subsystem within its hand-supportable housing for automatically activating in response to the detection of an object in its IR-based object detection field, the planar laser illumination array (to produce a PLIB in coplanar arrangement with said FOV), the linear-type image formation and detection (IFD) module, as well as the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, (ii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system in response to decoding a bar code symbol within a captured image frame, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

193. An automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a variable focal length/variable focal distance image formation optics and a field of view, (ii) a laser-based object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination array into a full-power mode of operation (to produce a PLIB in coplanar arrangement with said FOV), the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, in response to the automatic detection of an object in its laser-based object detection field, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system in response to decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.



194. An automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a variable focal length/variable focal distance image formation optics with a field of view (FOV), (ii) an ambient-light driven object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination array (to produce a PLIB in coplanar arrangement with said FOV) the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, in response to the automatic detection of an object via ambient-light detected by object detection field enabled by the image sensor within the IFD module, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system in response to decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

195. An automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a variable focal length/variable focal distance image formation optics with a field of view (FOV), (ii) an automatic bar code symbol detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination array (to produce a PLIB in coplanar arrangement with said FOV) the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, the image processing computer for decode-processing in response to the automatic detection of an bar code symbol within its bar code symbol detection field enabled by the image sensor within the IFD module, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system in response to decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

196. A manually-activated PLIIM-based hand-supportable area imager configured with (i) an area-type (i.e. 2D) image formation and detection (IFD) module having a fixed focal length/fixed focal distance image formation optics with a field of field of view (FOV), (ii) a manually-actuated trigger switch for manually activating the planar laser illumination array (to produce a PLIB in coplanar arrangement with said FOV), the area-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, in response to the manual activation of the trigger switch, and capturing images of objects (i.e. bearing bar code symbols and other

graphical indicia) through the fixed focal length/fixed focal distance image formation optics, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

5 197. An automatically-activated PLIIM-based hand-supportable area imager configured with (i) an area-type image formation and detection (IFD) module having a fixed focal length/fixed focal distance image formation optics with a FOV, (ii) an IR-based object detection subsystem within its hand-supportable housing for automatically activating in response to the detection of an object in its IR-based object detection field, the planar laser illumination array (to produce a PLIB in coplanar arrangement with said FOV), the area-type image formation and detection (IFD) module, as well as the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, (ii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system in response to decoding a bar code symbol within a captured image frame, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

10 198. An automatically-activated PLIIM-based hand-supportable area imager configured with (i) an area-type image formation and detection (IFD) module having a fixed focal length/fixed focal distance image formation optics with a FOV, (ii) a laser-based object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination array into a full-power mode of operation (to produce a PLIB in coplanar arrangement with said FOV), the area-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, in response to the automatic detection of an object in its laser-based object detection field, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system in response to decoding a bar code symbol within a captured image frame; and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

20 199. An automatically-activated PLIIM-based hand-supportable area imager shown configured with (i) a area-type image formation and detection (IFD) module having a fixed focal length/fixed focal distance image formation optics with a FOV, (ii) an ambient-light driven object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination array (to produce a PLIB in coplanar arrangement with said FOV), the area-type image formation and detection (IFD) module, the image frame grabber,

the image data buffer, and the image processing computer, via the camera control computer, in response to the automatic detection of an object via ambient-light detected by object detection field enabled by the image sensor within the IFD module, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system in response to decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

200. An automatically-activated PLIIM-based hand-supportable area imager configured with (i) an area-type image formation and detection (IFD) module having a fixed focal length/fixed focal distance image formation optics with a FOV, (ii) an automatic bar code symbol detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination array (to produce a PLIB in coplanar arrangement with said FOV), the area-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the image processing computer for decode-processing upon automatic detection of an bar code symbol within its bar code symbol detection field enabled by the image sensor within the IFD module, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system in response to decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

201. A manually-activated PLIIM-based hand-supportable area imager configured with (i) an area-type image formation and detection (IFD) module having a fixed focal length/variable focal distance image formation optics with a FOV, (ii) a manually-actuated trigger switch for manually activating the planar laser illumination array (to produce a PLIB in coplanar arrangement with said FOV), the area-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, upon manual activation of the trigger switch, and capturing images of objects (i.e. bearing bar code symbols and other graphical indicia) through the fixed focal length/fixed focal distance image formation optics, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

202. An automatically-activated PLIIM-based hand-supportable area imager configured with (i) an area-type image formation and detection (IFD) module having a fixed

focal length/variable focal distance image formation optics with a FOV, (ii) an IR-based object detection subsystem within its hand-supportable housing for automatically activating, in response to the detection of an object in its IR-based object detection field, the planar laser illumination array (to produce a PLIB in coplanar arrangement with said FOV), the area-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, (ii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system in response to decoding a bar code symbol within a captured image frame, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

203. An automatically-activated PLIIM-based hand-supportable area imager configured with (i) an area-type image formation and detection (IFD) module having a fixed focal length/variable focal distance image formation optics with a FOV, (ii) a laser-based object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination array into a full-power mode of operation (to produce a PLIB in coplanar arrangement with said FOV), the area-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via, the camera control computer, in response to the automatic detection of an object in its laser-based object detection field, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system in response to decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

204. An automatically-activated PLIIM-based hand-supportable area imager configured with (i) an area-type image formation and detection (IFD) module having a fixed focal length/variable focal distance image formation optics with a FOV, (ii) an ambient-light driven object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination array (to produce a PLIB in coplanar arrangement with said FOV), the area-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, upon automatic detection of an object via ambient-light detected by object detection field enabled by the image sensor within the IFD module, and (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame.

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205. An automatically-activated PLIIM-based hand-supportable area imager configured with (i) an area-type image formation and detection (IFD) module having a fixed focal length/variable focal distance image formation optics with a FOV, (ii) an automatic bar code symbol detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination array (to produce a PLIB in coplanar arrangement with said FOV), the area-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer for decode-processing of image data in response to the automatic detection of an bar code symbol within its bar code symbol detection field enabled by the image sensor within the IFD module, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system in response to decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

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206. A manually-activated PLIIM-based hand-supportable area imager configured with (i) an area-type image formation and detection (IFD) module having a variable focal length/variable focal distance image formation optics with a FOV, (ii) a manually-actuated trigger switch for manually activating the planar laser illumination array (to produce a PLIB in coplanar arrangement with said FOV), the area-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, in response to manual activation of the trigger switch, and capturing images of objects (i.e. bearing bar code symbols and other graphical indicia) through the fixed focal length/fixed focal distance image formation optics, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

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207. An automatically-activated PLIIM-based hand-supportable area imager configured with (i) an area-type image formation and detection (IFD) module having a variable focal length/variable focal distance image formation optics with a FOV, (ii) an IR-based object detection subsystem within its hand-supportable housing for automatically activating in response to the detection of an object in its IR-based object detection field, the planar laser illumination arrays (to produce a PLIB in coplanar arrangement with said FOV), the area-type image formation and detection (IFD) module, as well as the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, (ii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system in response to decoding a bar code symbol within a captured image frame,

and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

208. An automatically-activated PLIIM-based hand-supportable area imager configured with (i) an area-type image formation and detection (IFD) module having a variable focal length/variable focal distance image formation optics with a FOV, (ii) a laser-based object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination array into a full-power mode of operation (to produce a PLIB in coplanar arrangement with said FOV), the area-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, in response to the automatic detection of an object in its laser-based object detection field, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system in response to decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

209. An automatically-activated PLIIM-based hand-supportable area imager configured with (i) an area-type image formation and detection (IFD) module having a variable focal length/variable focal distance image formation optics with a FOV, (ii) an ambient-light driven object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination array (to produce a PLIB in coplanar arrangement with said FOV), the area-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, in response to the automatic detection of an object via ambient-light detected by object detection field enabled by the image sensor within the IFD module, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system in response to the decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

210. An automatically-activated PLIIM-based hand-supportable area imager configured with (i) an area-type image formation and detection (IFD) module having a variable focal length/variable focal distance image formation optics with a FOV, (ii) an automatic bar code symbol detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination array (to produce a PLIB in coplanar arrangement with said FOV), the area-type image formation and detection (IFD) module, the image frame grabber,



the image data buffer, and the image processing computer for decode-processing of image data in response to the automatic detection of an bar code symbol within its bar code symbol detection field enabled by the image sensor within the IFD module, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system in response to decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

211. A unitary (PLIIM-based) package dimensioning and identification system, wherein the various information signals are generated by the LDIP subsystem, and provided to a camera control computer, and wherein the camera control computer generates digital camera control signals which are provided to the image formation and detection (IFD subsystem (i.e. "camera") so that the system can carry out its diverse functions in an integrated manner, including (1) capturing digital images having (i) square pixels (i.e. 1:1 aspect ratio) independent of package height or velocity, (ii) significantly reduced speckle-noise levels, and (iii) constant image resolution measured in dots per inch (dpi) independent of package height or velocity and without the use of costly telecentric optics employed by prior art systems, (2) automatic cropping of captured images so that only regions of interest reflecting the package or package label require image processing by the image processing computer, and (3) automatic image lifting operations.

212. A bioptical-type planar laser illumination and imaging (PLIIM) system for the purpose of identifying products in supermarkets and other retail shopping environments (e.g. by reading bar code symbols thereon), as well as recognizing the shape, texture and color of produce (e.g. fruit, vegetables, etc.) using a composite multi-spectral planar laser illumination beam containing a spectrum of different characteristic wavelengths, to impart multi-color illumination characteristics thereto.

213. A bioptical-type PLIIM-based system, wherein a planar laser illumination array (PLIA) comprising a plurality of visible laser diodes (VLDs) which intrinsically exhibit high "mode-hopping" spectral characteristics which cooperate on the time domain to reduce the temporal coherence of the laser illumination sources operating in the PLIA, and thereby reduce the speckle-noise pattern observed at the image detection array of the PLIIM-based system.

214. A bioptical PLIIM-based product dimensioning, analysis and identification system comprising a pair of PLIIM-based package identification and dimensioning subsystems,



wherein each PLIIM-based subsystem produces multi-spectral planar laser illumination, employs a 1-D CCD image detection array, and is programmed to analyze images of objects (e.g. produce) captured thereby and determine the shape/geometry, dimensions and color of such products in diverse retail shopping environments.

215. A bioptical PLIM-based product dimensioning, analysis and identification system comprising a pair of PLIM-based package identification and dimensioning subsystems, wherein each subsystem employs a 2-D CCD image detection array and is programmed to analyze images of objects (e.g. produce) captured thereby and determine the shape/geometry, dimensions and color of such products in diverse retail shopping environments.

216. A unitary package identification and dimensioning system comprising: a LADAR-based package imaging, detecting and dimensioning subsystem capable of collecting range data from objects on the conveyor belt using a pair of multi-wavelength (i.e. containing visible and IR spectral components) laser scanning beams projected at different angular spacings; a PLIIM-based bar code symbol reading subsystem for producing a scanning volume above the conveyor belt, for scanning bar codes on packages transported therealong; an input/output subsystem for managing the inputs to and outputs from the unitary system; a data management computer, with a graphical user interface (GUI), for realizing a data element queuing, handling and processing subsystem, as well as other data and system management functions; and a network controller, operably connected to the I/O subsystem, for connecting the system to the local area network (LAN) associated with the tunnel-based system, as well as other packet-based data communication networks supporting various network protocols (e.g. Ethernet, Appletalk, etc).

217. A real-time camera control process carried out within a camera control computer in a PLIIM-based camera system, for intelligently enabling the camera system to zoom in and focus upon only the surfaces of a detected package which might bear package identifying and/or characterizing information that can be reliably captured and utilized by the system or network within which the camera subsystem is installed.

218. A real-time camera control process for significantly reducing the amount of image data captured by the system which does not contain relevant information, thus increasing the package identification performance of the camera subsystem, while using less computational resources, thereby allowing the camera subsystem to perform more efficiently and productivity.

5 219. A camera control computer for generating real-time camera control signals that drive the zoom and focus lens group translators within a high-speed auto-focus/auto-zoom digital camera subsystem so that the camera automatically captures digital images having (1) square pixels (i.e. 1:1 aspect ratio) independent of package height or velocity, (2) significantly reduced speckle-noise levels, and (3) constant image resolution measured in dots per inch (dpi) independent of package height or velocity.

10 220. An auto-focus/auto-zoom digital camera system employing a camera control computer which generates commands for cropping the corresponding slice (i.e. section) of the region of interest in the image being captured and buffered therewithin, or processed at an image processing computer.

15 221. A tunnel-type package identification and dimensioning (PIAD) system comprising a plurality of PLIIM-based package identification (PID) units arranged about a high-speed package conveyor belt structure, wherein the PID units are integrated within a high-speed data communications network having a suitable network topology and configuration.

20 222. A tunnel-type PIAD system, wherein the top PID unit includes a LDIP subsystem, and functions as a master PID unit within the tunnel system, whereas the side and bottom PID units (which are not provided with a LDIP subsystem) function as slave PID units and are programmed to receive package dimension data (e.g. height, length and width coordinates) from the master PID unit, and automatically convert (i.e. transform) on a real-time basis these package dimension coordinates into their local coordinate reference frames for use in dynamically controlling the zoom and focus parameters of the camera subsystems employed in the tunnel-type system.

25 223. A tunnel-type system, wherein the camera field of view (FOV) of the bottom PID unit is arranged to view packages through a small gap provided between sections of the conveyor belt structure.

30 224. A CCD camera-based tunnel system comprising auto-zoom/auto-focus CCD camera subsystems which utilize a "package-dimension data" driven camera control computer for automatic controlling the camera zoom and focus characteristics on a real-time manner.

225. A CCD camera-based tunnel-type system, wherein the package-dimension data driven camera control computer involves (i) dimensioning packages in a global coordinate reference system, (ii) producing package coordinate data referenced to the global coordinate reference system, and (iii) distributing the package coordinate data to local coordinate references frames in the system for conversion of the package coordinate data to local coordinate reference frames, and subsequent use in automatic camera zoom and focus control operations carried out upon the dimensioned packages.

226. A CCD camera-based tunnel-type system, wherein a LDIP subsystem within a master camera unit generates (i) package height, width, and length coordinate data and (ii) velocity data, referenced with respect to the global coordinate reference system  $R_{global}$ , and these package dimension data elements are transmitted to each slave camera unit on a data communication network, and once received, the camera control computer within the slave camera unit uses its preprogrammed homogeneous transformation to convert these values into package height, width, and length coordinates referenced to its local coordinate reference system.

227. A CCD camera-based tunnel-type system, wherein a camera control computer in each slave camera unit uses the converted package dimension coordinates to generate real-time camera control signals which intelligently drive its camera's automatic zoom and focus imaging optics to enable the intelligent capture and processing of image data containing information relating to the identify and/or destination of the transported package.

228. A bioptical PLIIM-based product identification, dimensioning and analysis (PIDA) system comprising a pair of PLIIM-based package identification systems arranged within a compact POS housing having bottom and side light transmission apertures, located beneath a pair of imaging windows.

229. A bioptical PLIIM-based system for capturing and analyzing color images of products and produce items, and thus enabling, in supermarket environments, "produce recognition" on the basis of color as well as dimensions and geometrical form.

230. A bioptical system which comprises: a bottom PLIIM-based unit mounted within the bottom portion of the housing; a side PLIIM-based unit mounted within the side portion of the housing; an electronic product weigh scale mounted beneath the bottom PLIIM-based unit, and a local data communication network mounted within the housing, and establishing a high-

speed data communication link between the bottom and side units and the electronic weigh scale.

231. A bioptical PLIIM-based system, wherein each PLIIM-based subsystem employs (i) a plurality of visible laser diodes (VLDs) having different color producing wavelengths to produce a multi-spectral planar laser illumination beam (PLIB) from the side and bottom imaging windows, and also (ii) a 1-D (linear-type) CCD image detection array for capturing color images of objects (e.g. produce) as the objects are manually transported past the imaging windows of the bioptical system, along the direction of the indicator arrow, by the user or operator of the system (e.g. retail sales clerk).

232. A bioptical PLIIM-based system, wherein the PLIIM-based subsystem installed within the bottom portion of the housing, projects an automatically swept PLIB and a stationary 3-D FOV through the bottom light transmission window.

233. A bioptical PLIIM-based system, wherein each PLIIM-based subsystem comprises (i) a plurality of visible laser diodes (VLDs) having different color producing wavelengths to produce a multi-spectral planar laser illumination beam (PLIB) from the side and bottom imaging windows, and also (ii) a 2-D (area-type) CCD image detection array for capturing color images of objects (e.g. produce) as the objects are presented to the imaging windows of the bioptical system by the user or operator of the system (e.g. retail sales clerk).

234. A miniature planar laser illumination module (PLIM) on a semiconductor chip that can be fabricated by aligning and mounting a micro-sized cylindrical lens array upon a linear array of surface emit lasers (SELs) formed on a semiconductor substrate, encapsulated (i.e. encased) in a semiconductor package provided with electrical pins and a light transmission window, and emitting laser emission in the direction normal to the semiconductor substrate.

235. A miniature planar laser illumination module (PLIM) on a semiconductor, wherein the laser output therefrom is a planar laser illumination beam (PLIB) composed of numerous (e.g. 100-400 or more) spatially incoherent laser beams emitted from the linear array of SELs.

236. A miniature planar laser illumination module (PLIM) on a semiconductor, wherein each SEL in the laser diode array can be designed to emit coherent radiation at a

different characteristic wavelengths to produce an array of laser beams which are substantially temporally and spatially incoherent with respect to each other.

237. A PLIM-based semiconductor chip, which produces a temporally and spatially coherent-reduced planar laser illumination beam (PLIB) capable of illuminating objects and producing digital images having substantially reduced speckle-noise patterns observable at the image detector of the PLIIM-based system in which the PLIM is employed.

238. A PLIM-based semiconductor which can be made to illuminate objects outside of the visible portion of the electromagnetic spectrum (e.g. over the UV and/or IR portion of the spectrum).

239. A PLIM-based semiconductor chip which embodies laser mode-locking principles so that the PLIB transmitted from the chip is temporal intensity-modulated at a sufficient high rate so as to produce ultra-short pulses of light ensuring substantial levels of speckle-noise pattern reduction during object illumination and imaging applications.

240. A PLIM-based semiconductor chip which contains a large number of VCSELs (i.e. real laser sources) fabricated on semiconductor chip so that speckle-noise pattern levels can be substantially reduced by an amount proportional to the square root of the number of independent laser sources (real or virtual) employed therein.

241. A miniature planar laser illumination module (PLIM) on a semiconductor chip which does not require any mechanical parts or components to produce a spatially and/or temporally coherence reduced PLIB during system operation.

242. A planar laser illumination and imaging module (PLIIM) realized on a semiconductor chip, comprising a pair of micro-sized (diffractive or refractive) cylindrical lens arrays mounted upon a pair of large linear arrays of surface emitting lasers (SELs) fabricated on opposite sides of a linear CCD image detection array.

243. A PLIIM-based semiconductor chip, wherein both the linear CCD image detection array and linear SEL arrays are formed on a common semiconductor substrate, and encased within an integrated circuit package having electrical connector pins, a first and second elongated light transmission windows disposed over the SEL arrays, and a third light transmission window disposed over the linear CCD image detection array.

5 244. A PLIIM-based semiconductor chip, which can be mounted on a mechanically oscillating scanning element in order to sweep both the FOV and coplanar PLIB through a 3-D volume of space in which objects bearing bar code and other machine-readable indicia may pass.

10 245. A PLIIM-based semiconductor chip embodying a plurality of linear SEL arrays which are electronically-activated to electro-optically scan (i.e. illuminate) the entire 3-D FOV of the CCD image detection array without using mechanical scanning mechanisms.

15 246. A PLIIM-based semiconductor chip, wherein the miniature 2D VLD/CCD camera can be realized by fabricating a 2-D array of SEL diodes about a centrally located 2-D area-type CCD image detection array, both on a semiconductor substrate and encapsulated within a IC package having a centrally-located light transmission window positioned over the CCD image detection array, and a peripheral light transmission window positioned over the surrounding 2-D array of SEL diodes.

20 247. A PLIIM-based semiconductor chip, wherein light focusing lens element is aligned with and mounted over the centrally-located light transmission window to define a 3D field of view (FOV) for forming images on the 2-D image detection array, whereas a 2-D array of cylindrical lens elements is aligned with and mounted over the peripheral light transmission window to substantially planarize the laser emission from the linear SEL arrays (comprising the 2-D SEL array) during operation.

25 248. A PLIIM-based semiconductor chip, wherein each cylindrical lens element is spatially aligned with a row (or column) in the 2-D CCD image detection array, and each linear array of SELs in the 2-D SEL array, over which a cylindrical lens element is mounted, is electrically addressable (i.e. activatable) by laser diode control and drive circuits fabricated on the same semiconductor substrate.

30 249. A PLIIM-based semiconductor chip which enables the illumination of an object residing within a 3D FOV during illumination operations, and the formation of an image strip on the corresponding rows (or columns) of detector elements in a CCD array.

35 250. A LED-based PLIM for use in PLIIM-based systems, wherein a linear-type LED, an optional focusing lens and a cylindrical lens element are mounted within compact barrel

structure, for the purpose of producing a spatially-incoherent planar light illumination beam (PLIB) therefrom.

5 251. An optical process carried out within a LED-based PLIM, wherein (1) the focusing lens focuses a reduced size image of the light emitting source of the LED towards the farthest working distance in the PLIIM-based system, and (2) the light rays associated with the reduced-sized image are transmitted through the cylindrical lens element to produce a spatially-coherent planar light illumination beam (PLIB).

10 252. An LED-based PLIM for use in PLIIM-based systems, wherein a linear-type LED, a focusing lens, collimating lens and a cylindrical lens element are mounted within compact barrel structure, for the purpose of producing a spatially-incoherent planar light illumination beam (PLIB) therefrom.

20 253. Another object of the present invention is to provide an optical process carried within an LED-based PLIM, wherein (1) the focusing lens focuses a reduced size image of the light emitting source of the LED towards a focal point within the barrel structure, (2) the collimating lens collimates the light rays associated with the reduced size image of the light emitting source, and (3) the cylindrical lens element diverges the collimated light beam so as to produce a spatially-coherent planar light illumination beam (PLIOB).

25 254. An LED-based PLIM chip for use in PLIIM-based systems, wherein a linear-type light emitting diode (LED) array, a focusing-type microlens array, collimating type microlens array, and a cylindrical-type microlens array are mounted within the IC package of the PLIM chip, for the purpose of producing a spatially-incoherent planar light illumination beam (PLIB) therefrom.

30 255. An LED-based PLIM, wherein (1) each focusing lenslet focuses a reduced size image of a light emitting source of an LED towards a focal point above the focusing-type microlens array, (2) each collimating lenslet collimates the light rays associated with the reduced size image of the light emitting source, and (3) each cylindrical lenslet diverges the collimated light beam so as to produce a spatially-coherent planar light illumination beam (PLIB) component, which collectively produce a composite PLIB from the LED-based PLIM.

35 256. A method of and apparatus for measuring, in the field, the pitch and yaw angles of each slave Package Identification (PID) unit in the tunnel system, as well as the elevation (i.e.



height) of each such PID unit, relative to the local coordinate reference frame symbolically embedded within the local PID unit.

257. Apparatus realized as angle-measurement (e.g. protractor) devices integrated within the structure of each slave and master PID housing and the support structure provided to support the same within the tunnel system, enabling the taking of such field measurements (i.e. angle and height readings) so that the precise coordinate location of each local coordinate reference frame (symbolically embedded within each PID unit) can be precisely determined, relative to the master PID unit.

258. An angle measurement device integrated into the structure of a PID unit by providing a pointer or indicating structure (e.g. arrow) on the surface of the housing of the PID unit, while mounting angle-measurement indicator on the corresponding support structure used to support the housing above the conveyor belt of the tunnel system.

259. An airport security system comprising:  
at least one PLIIM-based passenger identification and profiling camera subsystem, for capturing a digital image of the face of each passenger to board an aircraft at the airport,

(ii) capturing a digital profile of his or her face and head (and possibly body) using the LDIP subsystem employed therein, (iii) capturing a digital image of the passenger's identification card(s), (iii) indexing such passenger attribute information with the corresponding passenger identification (PID) number encoded within the PID bar code symbol that is printed on a passenger identification (PID) bracelet affixed to the passenger's hand at the passenger check-in station, and to be worn thereby during the entire duration of the passenger's scheduled flight;

a passenger identification (PID) bar code symbol and baggage identification (BID) bar code symbol dispensing subsystem, installed at the passenger check-in station, for dispensing (i) the PID bar code symbol and bracket to be worn by the passenger, and (ii) a unique BID bar code label for attachment to each baggage article to be carried aboard the aircraft on which the checked-in passenger will fly (or on another aircraft), wherein each BID bar code symbol assigned to baggage article is co-indexed with the PID bar code symbol assigned to the passenger checking in his or her baggage;

a tunnel-type package identification, dimensioning and tracking subsystem, including at least one PLIIM-based PID unit installed before the entry port of the X-radiation baggage scanning subsystem (or integrated therein), and also passenger and baggage data element

tracking computer, for automatically (i) identifying each article of baggage by reading the baggage identification (BID) bar code symbol applied thereto at a baggage check-in station of the airport security system, (ii) dimensioning (i.e. profiling) the article of baggage, (iii) capturing a digital image 2614 of the article of baggage, (iv) indexing such baggage attribute information with the corresponding BID number encoded into the scanned BID bar code symbol, and (v) sending such BID-indexed baggage attribute information to a passenger and baggage attribute RDBMS for storage as a baggage attribute record;

an x-ray (or CT) baggage scanning subsystem installed slightly downstream from the tunnel-based system, for automatically scanning each BID bar coded article of baggage to be loaded onto an aircraft using, for example, x-radiation, gamma-radiation and/or other radiation beams, and producing visible digital images of the interior and contents of each baggage article;

said passenger and baggage attribute RDBMS, being operably connected to said PLIIM-based passenger identification and profiling camera subsystem, said baggage identification (BID) bar code symbol dispensing subsystem, the tunnel-type package identification and dimensioning subsystem, and said baggage scanning subsystem, for maintaining coindexed records on passenger attribute information and baggage attribute information;

a computer-based information processing subsystem for processing passenger and baggage attribute records (e.g. text files, image files, voice files, etc.) and maintained in the RDBMS, to automatically mine and detect suspect conditions in such information records, as well as in records maintained in a remote RDBMS in communication with said processor via the Internet, which might detect a condition for alarm or security breach (e.g. explosive devices, identify suspect passengers linked to criminal activity, etc.); and

one or more security breach alarm subsystems, for detecting and issuing alarms to security personnel and/or other subsystems concerning possible security breach conditions during and after passengers and baggage are checked into an airport.

260. The airport security system of claim 259, wherein said passenger identification number is encoded within each BID bar code symbol affixed to the baggage articles carried by the passenger.

261. The airport security system of claim 259, wherein said PID and BID bar code symbols are constructed from 1-D or 2-D bar code symbologies.

262. A method of and apparatus for securing an airport system comprising the steps of:

- (a.) each passenger who is about to board an aircraft at an airport, going to a check-in station with personal identification (e.g. passport, driver's license, etc.) in hand as well as articles of baggage to be carried on the aircraft by the passenger;
- (b.) upon checking in with this station, issuing (1) a passenger identification bracelet bearing a PID bar code symbol, and (2) a corresponding PID bar code symbol for attachment to each package carried on the aircraft by the passenger;
- (c.) creating a passenger/baggage information record in the RDBMS for each passenger and set of baggage checked into the system at the check-in station;
- (d.) affixing a passenger identification (PID) bracelet to the passenger's hand at the passenger check-in station which is to be worn during the entire duration of the passenger's scheduled flight;
- (e.) automatically capturing (i) a digital image of the passenger's face, head and upper body, (ii) a digital profile of his or her face and head using the LDIP subsystem employed therein, and (iii) a digital image of the passenger's identification card(s);
- (f.) indexing each item of passenger attribute information with the corresponding passenger identification (PID) number encoded within the PID bar code symbol printed on the passenger identification (PID) bracelet affixed to the passenger's hand at the passenger check-in station;
- (g.) conveying each BID bar coded article of baggage through the tunnel-type package identification, dimensioning and tracking subsystem installed before the entry port of the X-radiation baggage scanning subsystem (or integrated therewith), and then through the X-radiation baggage scanning subsystem;
- (h.) automatically identifying, imaging, and dimensioning each bar coded article of baggage using optical radiation;
- (i.) automatically imaging dimensioning each bar coded article of baggage with x-radiation;
- (j.) automatically indexing each item of passenger and baggage attribute information with PID numbers and BID numbers, respectively, and storing said indexed item of passenger and baggage attribute information in the RDBMS for subsequent information processing;
- (k.) detecting suspicious conditions revealed by x-ray images of baggage using an x-ray monitor adjacent the x-ray scanning subsystem;
- (l.) running intelligent information processing algorithms each passenger and baggage attribute record stored in RDBMS as well as in remote RDBMSs containing passenger intelligence, in order to detect any suspicious conditions which may given

concern or alarm about either a particular passenger or article of baggage presenting concern or a breach of security;

(m.) determining if a breach of security appears to have occurred based on the results of step (l);

if a breach is determined prior to flight-time, then aborting the flight related to the suspect passenger and/or baggage, using security personnel; and

(n.) if a breach is detected after an aircraft has lifted off, then informing the flight crew and pilot by radio communication of the detected security concern.